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In how many ways can one age successfully? Patterns of wellbeing in the Lothian Birth Cohort 1936

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Declaration

I declare that all work presented in this thesis is my own. This work has not been submitted elsewhere for any other degree or qualification.

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Abstract

This thesis explored cognitive, psychosocial, and physical domains of wellbeing to find out their contribution to successful ageing in 70-year old individuals. Discovering groups with different patterns of wellbeing and their correlates may be informative about what constitutes success in old age. The objectives were to find out whether distinct groups within and across domains of wellbeing existed, and to find out the variables associated with the resulting groups. Using a cross-sectional design on the Lothian Birth Cohort 1936 (LBC1936, maximum n = 1091), which is a group of community-dwelling 70 year-olds, latent class analysis (LCA) was used to explore possible patterns of ageing in domains of cognitive, psychosocial, and physical function. Demographic, personality, and lifestyle variables that were not used in the LCA were used to characterise the resulting groups. The first study investigated cognitive ability. Individuals were grouped according to their scores on general cognitive ability (*g*), memory, and speed. I accepted a 3-group solution, including High- (n = 749, 69%), Average- (n = 303, 28%), and Low- (n = 39, 4%) cognition groups. Results indicated the presence of a strong dimension: people who did well on one component also did well on others, and failed to show any indication of uneven patterns of scores. In the second study on psychosocial wellbeing individuals were grouped according to their scores on physical function, quality of life, and emotional wellbeing. A 5-group solution was accepted. High (n =515, 42.7%), Average (n = 417, 38.3%), and Poor (n = 37, 3.4%) Wellbeing groups were identified; however, contrasting patterns of wellbeing across components were noticed in the two other groups: one group scored relatively highly on physical function, but low on emotional wellbeing (High Function/ Low Spirits, n = 60, 5.5%), while another group showed low physical function but relatively high emotional wellbeing (Low Function/High Spirits, n = 62, 5.7%). The next study investigated the physical fitness domain: groups were determined on physical fitness, lack of inflammation, and lack of morbidity. Two groups, High Physical Fitness (n = 757, 73.3%) and Low Physical Fitness (n = 291, 26.7%) were identified, which, like the cognitive domain, also indicated a continuous pattern of wellbeing. In the final study individuals were grouped according to their scores on all variables reflecting cognitive, psychosocial, and physical function. I identified 3 groups showing high or uneven patterns of wellbeing. The majority of individuals fell in the High Wellbeing group (n = 712, 65.3%). The two other groups contained either individuals scoring high on cognitive measures but poorly on psychosocial and physical measures (the Low Bio-Psychosocial group, n = 158, 14.5%), or individuals scoring low on cognitive measures but highly on psychosocial and physical measures (the Low Cognition group, n = 221, 20.3%). Intelligence, personality and health behaviours showed salient differences amongst the groups in all studies. Overall, high childhood cognitive ability, low scores on Neuroticism, and avoiding smoking were associated with high wellbeing. Overall, results demonstrated that although wellbeing in old age is primarily dimensional, there is evidence of groups showing uneven patterns of function, indicating that individuals could show relatively successful patterns in some areas of wellbeing despite relatively poor functioning in other areas. Awareness of the importance of lifelong intelligence and personality traits and health practices to later-life wellbeing amongst health-care professionals and policy-makers may help address risk-prevention, and improve compliance and patient-practitioner relationships to reduce health inequalities.

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

ADLs	Activities of daily living
AIC	Akaike information criterion
ANOVA	Analysis of variance
APOE e4	Apolipoprotein allele e4
BIC	Bayesian information criterion
BMI	Body mass index
BP	Blood pressure
CA	Cluster analysis
CI	Confidence interval
CRP	C-Reactive protein
CVD	Cardio-vascular disease
df	Degrees of freedom
ENT	Entropy
FVC	Forced vital capacity
FEV_1	Forced expiratory volume in 1 second
g	General cognitive ability
GMM	General mixture modeling
HADS	Hospital anxiety and depression scales
HSD	Honestly Significant Difference
KMO	Kaiser-Meyer-Olkin
LBC 1936	Lothian Birth Cohort 1936
LCA	Latent class analysis
LPA	Latent profile analysis
M	Means
MHT	Moray house test
ML	Maximum likelihood
MLR	Multinomial logistic regression
MMSE	Mini mental state exam
NART	National adult reading test
OR	Odds ratio
PCA	Principal components analysis
QOL	Quality of life
SD	Standard deviation
SMS	Scottish Mental Survey
SPSS	The Statistical Package for the Social Sciences
UN	United Nation
WAIS	Wechsler Adult Intelligent Scales
WHO	World health Organization
WMS	Wechsler Memory Scales

Chapter 1: Introduction: What is successful ageing?

1.1 Introduction

> "By 2050, the number of older persons in the world will exceed the number of young ones for the first time in history." (United Nations, 2001, p.xxviii)

The global population is currently over 7 billion, 650 million of whom are individuals over 60. This makes up one fifth of the population in the developed world. By 2050, these figures are expected to rise to 9 and 2 billion, respectively. Individuals over 60 will then make up one third of the population in the developed world (United Nations, 2001; World Health Organization, 2011). There is no dispute that we are living in an increasingly ageing population, but how successfully are we reaching old age?

Human ageing is a universal phenomenon, which has been studied extensively. The earliest known record on the topic describes the challenges of growing older. This was in 2500 BCE (de Beauvoir, 1972). Throughout history, leaders, philosophers, writers and artists alike all spoke of this process in life (e.g. Confucius, 551-479 BCE; Seneca, 4 BCE- CE 65; Virgil, 70-19 BCE; Cicero, 106-43 BCE; Shakespeare, 1564-1616). Up to the mid-1900s reaching old age was a rare thing only achieved by less than 2% of the population (Hauser, 1976; Robinson, 1989). The meaning of the term *old age* itself, which is widely classified as 60 years of age and over, is also changing due to the rising life expectancy and due to individuals staying longer in the workforce (UN, 2001; WHO, 2011). Although there have always been individuals who lived above the average life expectancy throughout history it was only in the mid 20th century that life expectancy started increasing on a global level. With the demographic shift and the phenomenon known as the greying of the Western world, ageing has been termed the "silent revolution" (Kalache, Barreto & Keller, 2005, p.30) and has sparked interest in both the field of academia (e.g. Baltes & Baltes, 1990; Bowling, 1993; Havighurst, 1961; Lupien & Wan, 2004; Palmore, 1979; Phelan & Larson, 2002; Rowe & Kahn, 1987; Rowe & Khan, 1997; Ryff, 1982; Schulz & Heckhausen, 1996; Williams & Wirths, 1965) and popular culture. Half the children born in the year 2000 onwards may reach 100 years (Vaupel, 2010; Christensen, Doblhammer, Rau et al., 2009). Reaching old age has become the norm rather than the exception. Individuals are not merely reaching old age because of the decrease in mortality but because when they reach it they are in better health (Vaupel, 2010). The period of morbidity is also being delayed (Christensen et al., 2009). Despite this, there is also the other side of the coin – developed countries with soaring obesity trends in the younger generations, which are associated with increased disability from an earlier age and costly care (Houston, Ding, Niklas et al., 2007; Malina, 2007; Matton, Duvigneaud & Wijndaele, 2007; Manton & Lamb, 2006). It may well be that the individuals reaching old age nowadays have led a healthier lifestyle than current younger generations. Life expectancy is longer today, and it may continue to rise, and more people are expected to live longer; but how many of these added years will be healthy years? The important shift in the research focus from ageing to *successful* ageing is timely. Successful ageing has only been a recent topic of interest (Bowling, 1993; Lupien & Wan, 2004; Palmore, 1979; Phelan & Larson, 2002; Ryff, 1982; Schulz & Heckhausen, 1996). Despite its positive connotations, however, this term implies an achievement of something desired suggesting 'winners' and 'losers' (Strawbridge, Wallhagen & Cohen, 2002).

The postponement of mortality and expected increases in population numbers of individuals aged 60 and over will require radical new solutions to revisions of the health care system, employment and retirement plans, and health and social policies (Christensen, Doblhammer, Rau & Vaupel, 2009; Dixon, 2012; Meth-Cohn, 2012; Olshansky, Carnes & Mandell, 2009; Sierra, Hadley, Suzman & Hodes, 2009; Vaupel & Loichinger, 2006; Vaupel & Gowan, 1986; Westerhout & Pellikaan, 2002; Vaupel, 2010). It will also require preventing and reducing disability to help older individuals maintain health, wellbeing and independence for as long as possible (Kirkwood, 2008). It is within the aims of recent projects (e.g. the European Innovation Partnership on Active and Healthy Ageing, 2012; European Study of Adult Well Being, ESAW, 2003) to add healthy life years to improve the overall wellbeing and quality of life of individuals in this age group. Ultimately this topic will become more relevant to all of us.

In this chapter, I first briefly review perspectives on ageing and successful ageing. This is followed by a discussion of the components and correlates of successful ageing. A discussion on how successful ageing is typically studied amongst individuals is then presented before I sum up this chapter and preview the thesis.

1.2 Perspectives through time

The theories covering this subject are numerous and dependant on the social, cultural, political, economic and demographic factors at the time. However, no one theory has been accepted. Historically, the very first perceptions linked to growing old were physical decrement conjoint with a sense of achievement. Ancient Greeks, such as Hippocrates (400 BC) and Seneca (4 BC – AD 65), as did the Romans, e.g. Virgil (70 – 19 BC) and Juvenal (60 - 130 BC) wrote about old age as a disease describing in detail illnesses and limitations that come with this period in life. Cicero (106 – 43 BC), however, spoke about it as a time of reflection and wisdom. The Bible also makes numerous references to old age. Psalm 90:10, for example distinguishes between the vigour of youth and the vulnerability of the old, and Psalm 71:9 speaks of the fear of rejection in old age. The benefits of a ripe old age and the Lord's rewards of longevity for being faithful are mentioned in a number of scripts, examples include Noah (Genesis 7:6), Abraham (Genesis, 25:8), and Moses (Deuteronomy, 34:7) to mention just a few. Artists between the 14th and 18th century viewed ageing as a sign of decline and a second childhood, e.g. Shakespeare in *As*

You Like It. This view prevailed up until the first half of 20th century but started to change with the increase in life expectancy. Because of the booming demographic changes in society, perspectives shifted to the social roles 60-year old individuals and older played, hence the emergence of sociological theories.

Sociological theories on ageing focused on the individual's role in society and how this may (or may not) change throughout the life-course, especially after the age of 60. A brief overview of the three major ones is given here. The Disengagement Theory (Cumming & Henry, 1961) defined old age as a period of declining role participation and slow disengagement from society suggesting a final stage of decreasing function and increasing passivity. This theory has been heavily criticised for its ageist tendencies and generalisations and its negative view of old age. It is now considered outdated (Bengtson & Putney, 2009). The Activity Theory (Havighurst & Albrecht, 1953; Maddox, 1965) rose out as an opposing view of the Disengagement Theory. It maintained that successful ageing took place if new roles replaced old ones enabling the individual to keep active in society and engage in social relationships. However, some individuals may be similarly happy to not take on new roles or develop new relationships; other actives may provide equal enjoyment and satisfaction such as writing, reading and gardening. Furthermore, this theory does not take into account health and economic inequalities, which may hinder social involvement or activities linked to the middle classes, such as volunteering (Bengtson & Putney, 2009). Lastly, the Continuity Theory (Atchley, 1989) modified the Activity Theory by adopting a life-course perspective in which the individual carries on with the usual activities and adapts to any changes that may continue to arise. The main limitation of this theory is that it only focuses on non-pathological ageing; it also ignores in what ways institutions and care-homes may affect individuals' lives.

During the 1980s and the 1990s psychologists also started to address this topic (e.g. Baltes & Baltes, 1990; Butt & Beiser, 1987; Erikson, 1984; Eriskon, Erikson & Kivnick, 1986; Rowe & Kahn, 1987; Rowe & Khan, 1997; Ryff, 1982; Ryff, 1989; Ryff & Marshall, 1999; Schulz & Heckhausen, 1996; Wong 1989). They wrote about finding personal meaning, purpose in life, personal growth and developing ego integrity in this life stage. Most prominent was Erikson's Psychosocial Theory (1959, 1984), which took on a life-span approach to explain the development of the ego through a series of eight stages from early infancy until later adulthood. Briefly, the theory postulates that with every stage in life the individual is faced with a crisis of which it will either be resolved in a negative or a positive way. Each new stage in life emerges from the previous ones depending on how they have been dealt with (positively or negatively). The final stage, reached in late adulthood, is ego-integrity vs. despair. Here the individual reflects on his past life, his present, and his future; a successful resolution would be ego integrity where acceptance of positive and negative experiences and of one's own self is embraced. During these decades formal models of the components of successful ageing also started to emerge, mainly due to the increasing life expectancy.

Although it was with Havighurst (1961) that successful ageing became an explicit theme in the academic world, Rowe and Kahn's (1987) distinction between usual and successful ageing, the latter of which was defined as low risk for disease and high function, was the most prevailing perspective. Their definition was later expanded to include avoidance of disease, maintenance of high cognitive and physical function, and active engagement with life (Rowe & Kahn, 1997). The McArthur Foundation Study of Successful Ageing in America, led by Rowe and Kahn themselves, aimed to determine what ageing involves; its research was based on their model by defining participants in their sample as ageing successfully only if they were functioning on a superior level than the average (Berkman, Seeman, Albert et al., 1993). This, however, is problematic. Successful ageing here was studied across cognitive and physical measures of performance. For someone to be classified as successful she had to perform at a higher level across all measures than the average, average being defined as "those who did not qualify in either the top or bottom tertiles of functioning" and were classified "on the basis of the poorest performance in any single area." (Berkman et al., 1993, p. 1131). Firstly, this is confusing; the average may be low in general, creating the Lake Woebegone effect where the belief of being above average amongst the 'successful' prevails, even if untrue. Secondly, because individuals were classified linearly (i.e. with predefined cut-off points for either high, average or low group membership - more on this below), if they performed highly in one of the areas of function, but low on the other, they were 'disqualified' from the successful ageing group and were put into either the average or low groups depending on how low their lowest score was. This failed to capture any differences between the 'average' and 'low' groups; it also treated 'success' as merely a score to be reached. This move in the ageing literature did not leave much room for differential ageing, whereby individuals may experience uneven profiles of wellbeing across multiple domains of function i.e. the possibility of high function in some domains co-existing with poor functioning in others.

Baltes and Baltes (1990) however, introduced a more individualised process of ageing in the 1990s. Their Selection, Optimization and Compensation Theory defined successful ageing as maximisation of gains and minimisation of losses by introducing the concepts of heterogeneity and plasticity. Here each individual adapted to losses and limitations by compensating and optimising his skills in other selected areas of life thereby allowing more variability in the ageing process. The individual redefines his goals as a way of adjustment to continuous changes. This theory moved away from maintaining high overall physical function towards psychological compensation and positive adaptation to any losses experienced. The Socio-Emotional Selectivity Theory proposed by Carstensen (1992) furthers Baltes and Baltes's (1990) theory, whereby the individual selects significant others from her own social circles for emotional closeness.

Since the 2000s onwards a more eclectic approach sparked interest in this field. Although some recent research still assumes that ageing is a monolithic entity focusing on physical health status (e.g. Bowling & Dieppe, 2005), efforts have been made to include and combine broader areas of physical, cognitive, and psychosocial function as well as individual's own perspectives in the definition of successful ageing. This is because of the increasing awareness of the importance each of these functions hold (Bowling & Dieppe, 2005; Depp & Jeste, 2009; Fiocco & Yaffe, 2010; Jeste, Depp & Vahia, 2010; Strawbridge, Wallhagen & Cohen, 2002; Young, Frick & Phelan, 2009).

Over the centuries, emphasis on the ageing process shifted reflecting the times and the historical context. A progression took place from the purely physical aspects and focus on decline in the olden days where one's physical strengths helped in survival, to seeping demographic shifts that placed emphasis on societal roles, to a move from ageing to successful ageing and its measurable components (mainly physical and cognitive), to the individual undergoing this process and coming to terms with it by finding personal meaning, and eventually culminating in recent efforts to combine all these perspectives.

1.3 Recent trends: What are the components and correlates of successful ageing?

Perhaps no one can capture the true essence of successful ageing better than a centenarian. These individuals exceed human life expectancy by 20 to 25 years. It seems that centenarians survive, escape, or delay disease (Evert et al., 2003; Engberg, Oksuzyan, Jeune et al., 2009). A number of projects (e.g. The EU-Integrated project on genetics of healthy ageing, Franceschi et al., 2007; The Lifelong Family Study, National Institute of Ageing, NIA 2008; and the Blue Zone Study, Buettner, 2008) are trying to develop a healthy model of ageing to identify key variables contributing to this extended longevity. Most research, however, is still struggling with agreeing on a definition of *successful ageing.*

The prevailing model (Rowe & Kahn, 1997) defines successful ageing in terms of freedom from disease and disability, high physical and cognitive function, and high social activity; success here is viewed as a state of being that can be measured objectively at any time-point. Other definitions (e.g. Baltes & Baltes, 1990; Baltes, 1997; Schulz, 1996) include the degree to which the individual successfully adapts to age-related changes; success here is more of a continuous process. Subjective measures whereby older individuals themselves contribute to the meaning of successful ageing, are also being included in the definition of successful ageing; some of these definitions include a sense of purpose, spirituality and a sense of accomplishment and contribution to life (e.g. Bowling & Dieppe, 2005; Bowling & Ilife, 2006; Montross et al., 2006; Phelan, Anderson, LaCroix et al., 2004; Strawbridge, Wallhagen & Cohen, 2002; von Faber, Bootsma-van der Wiel, van Exel, et al., 2001). As an optimal state, the World Health Organisation (2002) defines healthy ageing as complete physical, mental and social wellbeing, and not just absence of disease.

In a recent review on the operationalized definitions of successful ageing in 29 studies, Depp and Jeste (2009) found that the most commonly used domain was physical functioning as measured either by objective measures such as grip-strength or walk-time, or by self-reporting such as activities of daily living (ADLs); this was followed by cognitive functioning as measured by the Mini-Mental Scale Examination (MMSE) or self-reported memory functioning; the third most commonly used domain was social wellbeing and life-satisfaction. Components of physical functioning and freedom from disability featured in all definitions of successful ageing; however, other components such as cognitive functioning, social engagement, emotional wellbeing, environmental and financial security and quality of life did not feature in more than 50% of the studies, and only 38% included absence of cognitive impairment (Depp & Jeste, 2009). The authors found that up to fourteen different components ranging from disability, physical function, cognitive function, productive engagement to self-rated health and personality were used to define this concept, and that most studies included measures of cognitive ability, physical function and freedom from disease, psychosocial wellbeing and emotional stability to define successful ageing (Depp & Jeste, 2009; Fiocco & Yaffe, 2010; Jeste, Depp & Vahia, 2010; Rowe & Kahn, 1997). Recent research (Phelan et al., 2004; Montross et al., 2006) has shown that so far there is no one definition of successful ageing that has endorsed all domains of function considered important to older individuals themselves; these included components of physical, functional, social, and psychological wellbeing.

Ageing literature (past and present) shows that researchers have studied wellbeing in old age focusing on either one domain of function (e.g. Lovden et al., 2005 only focused on cognition), a combination of two domains (e.g. Andrews et al., 2002 studied physical and cognitive functioning; Bosworth & Schaie, 1997 studied health and social inclusion), or adopted a broader approach using multiple domains (e.g. Smith & Baltes, 1998 studied cognitive function, personality and self, and social relationships; Garfein and Herzog, 1995, focused on physical function, cognitive function, emotional wellbeing and social involvement). Research into correlates of successful ageing has increasingly led to the realisation that some domains of function are highly correlated (e.g. physical and cognitive function, psychosocial and emotional wellbeing, and cognitive and emotional wellbeing) and that studying just one area is too narrow (Baltes & Frieder, 1997; Charles & Carstensen, 2009; Charles & Cartensen, 2010; Christensen et al., 2001; Deary et al., 2006; Goh & Park, 2009; Lemon et al., 1972; Lindenerger & Baltes, 1994; Anstey & Smith, 1999; Gow, Pattie, Whiteman et al., 2007; Rattan, 2006; Salthouse, 2009; Sohal et al., 2002).

In Phelan and Larson’s (2002) study on current definitions and predictors of successful ageing, the authors found that typically studies that define success in terms of high functioning, identify freedom from disease, physical activity, and social engagement as predictors of successful ageing. They also found that other studies use these same components to define successful ageing. The concept of successful ageing itself is sometimes referred to as “healthy ageing” (Peel, McClure & Bartlett, 2005); “ageing well” (Viallant & Mukamal, 2001), and “productive ageing” (Butler, 1988) adding to the heterogeneity of this phenomenon. These terms and meanings of success are usually reflective of the researcher’s own definitions (Phelan & Larson, 2002). Given the variability and the little consensus on the meaning of this term (Depp & Jeste, 2009; Fiocco & Yaffe, 2010; Jeste, Depp & Vahia, 2010) it is difficult to know what constitutes success, what is associated with it, and if there are different ways to reach it.

Most studies (Andrews, et al., 2002; Berkman et al., 2003; Garfein & Herzog, 1995; Hsu & Jones, 2012; Strawbridge et al., 2001) have based their research on Rowe and Kahn’s (1997) definition of successful ageing. This means that a lot of what is known about successful ageing revolves around the concepts of freedom from disease, high physical and cognitive function, and social engagement. It is however, still unknown how much these domains affect and reflect each other’s functioning.

Research so far has shown that high cognitive function is an important associate of autonomy, physical health, functional independence, quality of life, and low levels of disease and mortality (Charles & Carstensen, 2009; Deary et al., 2004; Fiocco & Yaffe, 2010; Lindenberger & Baltes, 1994; Menac, 2003; WHO, 2002). It is also related to being more able to adjust to and deal with consequences of disease (Whalley et al., 2004). It seems clear that cognitive ability is a key component in the functioning of other domains of wellbeing, especially because with its decline (e.g. in mild cognitive impairment or in dementia) the possibility of a good quality of life, a high level of independence and autonomy is uncertain despite the possibly remaining high physical function and lack of illnesses.

Poor physical health, functional limitations, physical disability or dependence on others are associated with feelings of depression (Fiske, Gatz & Pedersen, 2003; Friske, Loebach Wetherell & Gatz, 2009; Bain, Lemmon, Teunisse, et al., 2003). In old age this is manifested differently from adulthood, mainly through cognitive dysfunction, sleep disturbance, anhedonia, and feelings of hopelessness (Fiske, Loebach Wetherell & Gatz, 2009). Although age *per se* is not a risk factor for depression (Baltes & Mayer, 1999), major risk factors include co-morbidity, functional disability, cognitive dysfunction, and social isolation (Roberts, Kaplan, Shema, et al., 1997), most of which are more likely to be present in old age. Coping with these issues may reflect good social resources and successful psychosocial adaptation including resilience and positive attitudes (e.g., Fratiglioni, Wang, Ericsson, Maytan & Winblad, 2000; Okabayashi, Liang, Krause, Akiyama & Sugisawa, 2004; Gow et al., 2004; Friedman, Kern & Reynolds, 2010; Kruger, et al., 2009; Depp, Vahia & Jeste, 2010).

Therefore it may be that decline in one domain of function is compensated with high functioning in another. Social engagement, for example, may act as a protective factor against stress, loneliness and depression especially if physical illness is present; it may also be protective of mental decline and emotional instability (Gow, Pattie, Whiteman, et al., 2007; Holtzman, Rebok, Saczynski, et al., 2004; Charles & Carstensen, 2009; Kruger, Wilson, Kamenetsky, et al., 2009; Rowe & Kahn, 1987). Although it is unclear if social activity helps in keeping feelings of stress and depression away or if individuals seek out social activity because they have been already feeling lonely and stressed, and have reached out for ‘help’ by involving themselves in more social activities, a good network of support may contribute to psychological wellness and a sense of purpose that older people themselves seem to value. A physically healthy individual may feel lonely and depressed, but a person with a chronic disease living in a supportive environment and is involved in social activities may feel fulfilled.

There are other known domains and associates of successful ageing. High scores on positive personality traits (e.g. Conscientiousness and Agreeableness), high cognitive skills, a healthy diet, exercise, avoiding smoking, high childhood cognitive ability, a social network and optimism and resilience have all been shown to contribute to greater physical, social and emotional wellness in later life (Baltes & Frieder, 1997; Deary et al., 2007; Depp & Jeste, 2009; Gow, Pattie, Whiteman et al., 2007; Jeste, Depp & Vahia, 2010; Parslow, Lewis & Nay, 2011; Phelan & Larson, 2002; Roberts, Kuncel, Shiner et al., 2007). Although these may add to the multitude of definitions and components in the literature, they may also help in shaping a more thorough assessment of what success may involve and if it is achievable in just one or multiple ways.

We now know roughly how successful ageing is typically defined, but how are people typically grouped? Would someone in good physical shape but with declining cognitive ability still be considered *successful*? We know that the presence of cognitive impairment, sensory deprivation, physical disease, and poor surroundings may hinder the ageing process (Vaupel, 2010), but would it still be possible to age successfully if one of these factors is present? Or is it necessary to be functioning well across all measures of function? Two dominant perspectives that address this issue in opposing ways are discussed in next section.

1.4 Is successful ageing still possible even if one of the domains shows pathological patterns in the ageing individual? : Linear and process perspectives

It is increasingly recognized that successful ageing in its most complete form involves several domains of function, including cognitive, physical, psychological, social, and emotional; however, the internal relationships between domains of ageing are disputed (von Faber et al., 2012). The question is: what is the relative importance of each domain's role in successful ageing, and are these domains associated closely with each other or are they independent of each other? Furthermore, would successful ageing still be possible if one of the above domains has factors that are classified as having declined to a non-normative level?

Several different perspectives address these questions. Most perspectives explore continuity vs. discontinuity processes in ageing and cognitive ageing (Baltes, 1973; Rowe & Kahn, 1987; Fozard, Metter & Brant, 1990; Gerok & Brandtstädter, 1992; Berkman, et al., 1993; Lindenberger & Baltes, 1994; Baltes & Lindenberger, 1997; Andrews, Clark & Luszcz, 2002; Menec, 2003). Continuity approaches explain life-span developmental outcomes as the ultimate result of a stable and continuous life-history of individual differences that culminates in old age (Hertzog & Schaie, 1986, 1988; Lindenberger & Baltes, 1994, 1997). For example, the common cause hypothesis, first applied to cognition and sensory functions (Lindenberger & Baltes, 1994; Baltes & Lindenberger, 1997), suggests that functioning in old age lies on a single spectrum ranging from low to high, influenced by a common underlying mechanism (brain integrity/physiological architecture of the brain) affecting age-related declines in both sensory and cognitive processes. Because supporters of this hypothesis claim that the association between these two processes becomes stronger with increasing age, they also suggest that old individuals are across a dimension of high, medium, or low across domains of wellbeing depending on how well or poorly they are ageing (e.g. Anstey & Smith, 1999; Andrews, Clark & Luszcz, 2002; Berkman, et al., 1993; Christensen, Mackinnon, Korten & Jorm, 2001; Duylay & Murphy, 2002; Lindenberger & Baltes, 1997; Mackinnon, Christensen & Jorm, 2006; Menec, 2003; Rabbitt, 1993; Salthouse, Hambrick & McGuthry, 1998; Salthouse, Hanock, Meinz et al., 1996). An alternative but related explanation to this is the sensory deprivation hypothesis (Sekuler & Blake, 1987), which posits that the correlation between sensory and cognitive function is caused by the decline of sensory stimulation consequently influencing cognitive functioning. Other researchers (Christensen et al., 2001) have also pointed out that the possible casual direction could also be explained the opposite way, i.e. lowered cognitive function may affect sensory decline. Ultimately, the basis of this approach lies in the association between cognitive and sensory function in old age, which implies a decline in synchrony influenced by an underlying common (latent) mechanism that is responsible for their association. The result is either a decline in all or none of the functions; hence the individual is either ageing well or not. This approach is attractive because it implies the possibility of reaching old age relatively free of age-related disease; however, when applied against multiple markers of ageing (e.g. cognitive, physical, psychological, social, emotional), most individuals do not fall into one category consistently high or low across all markers (Smith & Baltes, 1997). Garfein and Herzog (1995) found that only 4% of their sample fell in the top most quartile for all measures of functional status, cognitive status, affective status, and productive involvement, with a linear age-related decrease in that the older the group-mean individuals belonged to (60-69, 70-79, 80+) the less likely they were to score in the highest 25th percentile on all criteria. This approach implies that high functioning in old age is reached by only a limited segment of the population (Lupien & Wan, 2004). Although, both cognitive and sensory/functional changes take place over time, and to some degree changes in one possibly influence changes in another, this approach fails to recognize the heterogeneity amongst older individuals (Young, Frick & Phelan, 2009; Christensen & Mackinnon, 2004). For example, it does not take into account the possibility of profiles of individuals who may be functionally impaired but are still cognitively intact (Lupien and Wan, 2004; Lupien & Wan, 2011; Masoro, 2011).

The discontinuity approach on the other hand considers ageing a process comprising multiple domains; some individuals can show good or poor wellbeing consistently across physical and psychosocial aspects of wellbeing, whereas others are good in one domain and poor in another (Baltes & Baltes, 1990; Grundy, Fletcher, Smith & Lamping, 2007; Young, Frick & Phelan, 2009). In contrast to the linear dimension adopted by continuity perspectives, this approach recognises the heterogeneity and diversity in ageing populations as emphasised by several authors (e.g. Kirkwood, 2008; Christensen, Johnson & Vaupel, 2006; Lafortune, Bèland, Bergman & Ankri, 2009; Moerley, 2009); hence the possibility of unevenness across domains of high function coexisting with impairments and limitations in other domains. This is especially because physical health and cognitive function show the greatest variability in old age (Baltes, Staudinger & Lindenberger, 1999; Salthouse & Ferrer-Gaja, 2003); this along with further lifelong differences in health, personality and social attitudes may also contribute to giving rise to uneven and numerous profiles of wellbeing (Garfein & Herzog, 1995). Unevenness across variables such as these is thought to reflect a mixture of gains and losses brought about by different causes and affecting individuals in different ways (Gerstorf, Smith & Baltes, 2006; Baltes, Lindenberger & Staudinger, 2006). Baltes and Baltes's (1990) theory on selective optimization with compensation, illustrates this. Their theory states that individuals can still maintain high psychological wellbeing even if physically unwell. Here the individual selects domains for optimization to compensate and redefine his goals. Related theories include the Socio-Economical Selectivity Theory (SST, Carstensen, 1992, 1995; Castensen, Isaacowitz & Charles, 1999; Charles & Carstensen, 2009) and the Strength and Vulnerability Integration Theory (Charles & Piazza, 2009), according to which the individual changes his motivations and perspectives making emotional experiences more meaningful due to awareness on time constraints and remaining strengths and limitations.

The possibility of uneven profiles allows the person-environment fit Baltes and Baltes (1990) talk about. This is the adjustment of the individual, who is undergoing continuous developmental change to his environment. For example, if an individual is diagnosed with a chronic disease e.g. diabetes, he may adjust to it by organizing walking groups with friends to become engaged in physical activities and find their support in coping with the recent diagnosis; or if a relatively healthy individual has been recently bereaved, she might join a charity and spend more time volunteering and being surrounded by friends for support (Baltes & Baltes, 1990; Brandstader & Rothermund, 2002; Heckhausen & Schulz, 1995; Young, Frick & Phelan, 2008).

Cross-sectional work studying patterns of wellbeing shows that differential or uneven profiles exist at any age from adulthood to old age (e.g., Ko et al., 2007). In Smith and Baltes's (1997) study on psychological functioning the authors applied cluster analysis on measures of cognitive ability, personality and self, and social wellbeing amongst individuals between the ages of 70 and 103 in the Berlin Ageing Study (BASE; Baltes, Mayer, Helmchen, et al., 1993). They extracted 9 clusters of individuals showing different profiles of psychological functioning and aimed to find out the functional status of these. They ranked the profiles from high to low desirability in terms of number of positive or negative psychological attributes, for example a high desirable profile had high cognitive ability, had high scores on the Extraversion trait, and was not lonely; and a low desirable profile had severe cognitive impairment, scored highly on the Neuroticism trait, scored highly on loneliness, scored low on the Extraversion trait and had low internal control (the belief that one's outcomes in life are a results of one's own actions). The authors found that most individuals fell in the 'moderately positive profile', which had good cognitive ability, high Extraversion and high goal investment (here this means engagement in family and social projects). However, a lot of individuals fell in the middle, showing uneven profiles, e.g. one group was defined as having high cognitive function, high loneliness, low Extraversion and low internal control; another group's characteristics included high scores on the Neuroticism trait, high perceived control and high external control (the belief that actions of other people will determine what happens to oneself). This study showed that variables that are not typically correlated, such as Neuroticism and perceived support (e.g. in Cacioppo, Hughes, Waite, Hawkley & Thisted, 2006) were present in the same cluster of individuals. External variables (which were not entered in the cluster analysis and were external to psychological wellbeing), such as education, physical functionality, and medical illness, were also used to describe the nine profiles. The authors found that the more desirable profiles also had more years in education, better health, and better physical wellbeing.

Smith and Baltes's (1997) results displaying numerous uneven profiles were further supported by a study on couples' wellbeing in old age. Ko et al. (2007) grouped couples on their scores in areas of cognition, physical health, social support, personality, and marriage satisfaction. They extracted a 2- and 4-profile solution from latent class analysis. Both solutions contained a group with the majority of the sample displaying favourable characteristics, such as high cognitive function, good social support, good physical health, marital satisfaction and low scores on Neuroticism and Hostility. In the 2-profile solution, the couples in the second group were unsatisfied in their marriage, and scored high on Neuroticism and Hostility; however, their health was average. In the 4-profile solution, the other three groups were either 1) physically healthy and with high cognitive function but martially unsatisfied and with poor social support and high on Neuroticism and Hostility; 2) physically unhealthy, displayed poor cognitive function but were maritally satisfied with high social support, or 3) had markedly poor cognitive function but had average scores on the rest of the variables. This study further emphasized uneven profiles across domains in that marital satisfaction and good health were not always associated, as the authors had expected.

Other studies that explored profiles of wellbeing have also found uneven profiles across groups of individuals e.g. Prucho et al. (2010) identified four groups using objective (physical function and disease) and subjective (self-rated health) indicators: one group was successful on both objective and subjective indicators, another was successful on subjective indicators only, another group was successful on objective indicators only, and the last group was not successful on either objective or subjective indicators. In Hsu and Jones's (2012) study on multiple trajectories of successful ageing, the authors also identified four groups - successful ageing, usual (in the old-old of their sample) or financially insecure (in young-old) ageing, health-declining, and care-demanding (needed constant care), which were defined in terms of chronic disease and physical function, emotional support and depressive symptoms, social participation and social satisfaction.

Research carried out from this perspective shows that when multiple markers of ageing are defined, individuals do not typically fall under just one category (Garfin & Herzog, 1995; Gerstof, Smith & Baltes, 2006; Ko, Berg, Butner, Uchino & Smith, 2007; Smith & Baltes, 1997; Parslow, Lewis & Nay, 2011; Tumminello, Micciche, Dominguez, Lamura, et al., 2011). Multiple domains ranging from physical, functional, cognitive, social, emotional, psychological, to spiritual are usually included in studies adopting this approach especially since heavy influence is placed on the individual's experience (Crowther, Parker, Achenbaum et al., 2002; Garfin & Herzog, 1995; Ko et al., 2007; Lafortune et al., 2009; Phelan, Anderson, LaCroix et al., 2004; Smith & Baltes, 1997; Young, Frick & Phelan, 2009). For example, Motta et al. (2005) used cognitive function, physical function, and emotional wellbeing to group centenarians; and Chou and Chi (2002) and Ng et al. (2009) used cognitive function, physical function, emotional status and social engagement in their cross-sectional studies; Prucho et al. (2010) used both objective and subjective criteria of wellbeing; and Ko et al. (2007) also included marital satisfaction.

Although the discontinuity approach allows more flexibility in studying peoples' patterns of wellbeing in old age, there is some inconsistency to how it is applied. For example, some authors (Ko et al., 2007) input variables that are not applicable to all ageing individuals, such as marriage satisfaction (some individuals may have never married, are widowed, or divorced), to explore differences amongst the groups, and some researchers have used only one or two aspects of wellbeing in old age (e.g. psychological wellbeing, Smith & Baltes, 1997; cognitive and physical function, Baltes & Lindenberger, 1994). Applying different variables in different studies will obviously result in different findings. Furthermore, variables that are not age-dependent, such as marriage-satisfaction, do not reveal age-specific patterns. It would be more useful in old age research to just focus the main analysis on a few core variables that are likely to change with age e.g. cognitive function, physical function, or are dependent on the individual's time point in life e.g. quality of life, and use any further variables unrelated to age (e.g. personality and demographic information) as external indicators used to generate profiles after the groups have been established. Some authors (e.g. Lafortune et al., 2009) have already adopted this approach. A lot of variables (depending on what definition the authors adopt to define successful ageing) have been used to group individuals, which is not helpful in trying to reach reliability across studies. Furthermore, most of the studies employ older techniques (e.g. cluster analysis) that are now being replaced by newer methods (e.g. latent class analysis, more on this in Chapter 2, *Methodology*) and adopted more frequently (e.g. in Hsu & Jones, 2010; Lafortune et al., 2009; Prucho et al., 2010), which offer more advantages to group individuals.

Although researchers seem to have adopted either the continuous or discontinuous approach, it might possibly be that both are plausible. For example, cognitive and physical functioning seem to be highly associated (Baltes & Lindenberger, 1994), and individuals scoring high in one area possibly score high in the other; however, when adopting a more multidimensional approach e.g. including areas of function relating to psychosocial and emotional wellbeing, results might suggest a different pattern (e.g. Smith & Baltes, 1997). It would be a step forward to adopt a more rigorous, focused approach to explore any existing differences amongst subgroups of individuals across the major domains of function adopted in the literature, namely physical, cognitive, social and emotional function. The heterogeneity of ageing is well-recognised (Kirkwood, 2008; Lafortune et al., 2009); however, a degree of similarity across domains of function and across individuals may also be a likely result, e.g. high performing individuals seem to do well in most areas of life but individuals with a more mixed profile of performance may do well in some areas and poorly in others (e.g. Ko et al., 2007; Smith & Baltes, 1997). For example, Smith and Baltes's (1997) study demonstrated the possibility of this: the high performing group seemed to have better levels of performance in other areas of life, but other groups had mixed profiles. Therefore, although the linear and process approaches may seem incompatible, it may be that both may apply in different domains of function across individuals. In this study I wanted to address previous methods' limitations by studying domains of function independently of each other and then together to find out how individuals grouped together. This is discussed more in Section 1.6.

1.5 Concluding remarks

Ageing is a lifelong heterogeneous process (Jeste, Depp & Vahia, 2010; Whitbourne, 2001) affected and influenced by many intrinsic characteristics (e.g. personality) and external factors (e.g. environmental surroundings) (Fiocco & Yaffe, 2010; Jeste, Depp & Vahia, 2010).

In this chapter I aimed to illustrate how researchers have focused on different areas of successful ageing ranging from physiological processes, social role changes, psychological stages to interpersonal growth. Early definitions focused mostly on the physical aspect of ageing, in which absence of disease and loss-of-function were the focal points of success. This has moved gradually to include other psychological, sociological, cognitive and emotional processes taking place and contributing to the wellbeing of the individual and his 'success' during this period in life. An eclectic approach seems to have been gaining strength in the 21st century whereby all these areas are encouraged and aimed at being studied together.

Definitions of the meaning of successful ageing will continue to change according to societal and cultural changes and biological norms (Baltes & Carstensen, 1996). It is precisely for this reason that a definition of successful ageing should include multiple domains of function. A flexible definition that includes outcomes defined by different authorities (e.g. scientists, lay people), different criteria (subjective and objective), and different norms (e.g. statistical, functional) can be a likely objective, which may help individuals guide and find their own personal ideals and goals (Baltes & Carstensen, 1996). Clinicians should discuss directly with their patients their goals and ideals for old age to reach a mutual understanding of their priorities in their later years (Phelan & Larson, 2002). Therefore, not having an established definition is not necessarily a bad thing: striving towards a common goal may be reached through different paths. Setting out to find “a few key secrets to longevity” (Vaugel, 2010, p.59) may lead to broad and encompassing conclusions as Vaugel (2010) found out: There are many ways of living a long healthy life. It is within the aim of this thesis to find out some of these ways.

The cohort studied in this thesis, the Lothian Birth Cohort 1936 (LBC1936) (Deary, Gow, Taylor, Corley et al., 2007; Deary, Gow, Pattie & Starr, in press), an ageing cohort for whom data on childhood cognitive ability is available, constituted a relatively healthy and high functioning group of community-dwelling 70-year olds. It can be considered as comprising a group of 1091 elite elders who have returned to be tested, after 60 years and who have avoided death in the meanwhile. This study only makes use of baseline measures collected in 2007, for which the total number of participants amounted to 1091.

1.6 Aims of the thesis

In this thesis I adopted a multidimensional perspective by studying cognitive ability, psychosocial wellbeing and physical fitness in the LBC1936 at age 70. By finding out about scores on cognitive, physical and psychosocial measures in 70-year old individuals I aimed to discover the patterns of wellbeing in the LBC1936 and if it was still possible to find high wellbeing patterns even when one of these domains showed poor patterns of function. Specifically my aims in this thesis were to:

1. Explore the structure of the domains of wellbeing by constructing three major domains of function widely studied in ageing literature, namely cognitive, psychosocial and physical, out of related variables from the LBC1936;
2. Find out whether distinct groups within and across domains of cognitive, psychosocial and physical function exist in order to characterize their profile of wellbeing at age 70. I also wanted to find out if uneven profiles of wellbeing were present or if wellbeing showed a dimensional pattern of consistently high- or low- scoring individuals within and across domains;
3. Find out the associates of any resulting groups by identifying external variables —those other than those used to make the classifications—associated with membership in any observed profile groups.

By addressing these three aims my goals were to develop a comprehensive descriptive picture of wellbeing in 70 year-old individuals. The use of external variables (Aim 3) can be helpful in identifying differences relating to specific groups of individuals and help in finding out which variables are associated with which specific subgroups. This would be helpful in two ways: first this would be informative about any high performing group (relative to the rest) about what constitutes high wellbeing in old age. Secondly, it would also indicate which variables affect low performing groups the most. This would also have the potential in informing health-care professionals and policy-makers on addressing clinical issues on risk preventions, improved compliance and patient-practitioner relationships.

Each of the three domains explored all three aims individually; first the domains were studied separately - Cognitive Function in Chapter 3; Psychosocial Wellbeing in Chapter 4, Physical Fitness in Chapter 5, and finally together in

Chapter 6. The former three explored profiles of wellbeing within domains, and the latter one, across domains. The last chapter, Chapter 7 is an overall discussion of the results. But firstly, a thorough description on the LBC 1936, the variables I used and the procedures I adopted to achieve my aims are discussed in the next chapter, Methodology.

2. Methodology

The study's sample consisted of members of the Lothian Birth Cohort 1936 (LBC1936). They form a narrow-age cohort of individuals born in 1936 that has been extensively assessed (see Deary et al., 2007; Deary, Gow, Pattie & Starr, in press), including screening for dementia. This chapter presents a comprehensive description of this sample. This includes an overview of the Scottish Mental Survey (SMS1947) the cohort took in 1947 along with its aims, and the procedure that was carried out for testing and follow-up sessions; a description of the recruitment of the LBC1936 and the aims and procedure of the follow-up; and finally a description of the battery of cognitive tests, biomedical and physical measures, and social questionnaires that were applied in the LBC1936 and that were analysed in this thesis. This is followed by a description of the statistical methods and techniques I used and the procedure I applied to analyse the data.

2.1 The Scottish Mental Survey 1947

On 4th June 1947, all Scottish children born in 1936 sat a mental test, known as the Scottish Mental Survey (SMS1947) at their local school. This was a follow-up of the Scottish Mental Survey of 1932, and the second nation-wide survey conducted in Scotland. The aim of the first survey was to assess the intelligence of Scottish children, the aim of the second survey was to investigate whether the intelligence of 11- year old Scottish children was declining, and more specifically to explore whether lower ability parents have more children;

> The inquiry reported in this volume was begun in the hope that it might throw light on the causes of a remarkable quantitative social fact, namely, that the results of intelligence tests show that the average score of members of large families is less than that of small families. It was feared that this might be leading to a steady fall in the national intelligence, if its cause is that intelligent parents are limiting their families. (Scottish Research in Education, 1949, p. vii).

As in 1932, there was nationwide cooperation, and all schools received test instructions and papers to administer to all 11- year old children. It was the same test as that administered in the SMS1932. The SMS is a version of the Moray House Test (MHT) Number 12, which was developed by Godfrey H. Thomson (1940) in order to test English students sitting for secondary school examinations. With Thomson's help, three other parts were added to the MHT for the SMS1932 and as a result the Group Test, which consisted of a preliminary practise test, two picture tests and the verbal test (i.e. the MHT), was developed. However, this was not done in the SMS1947, and only the MHT was administered. This required literacy and numeric understanding. It included answering questions relating to following directions, word opposites, word classification, mixed sentences, spatial items, reasoning, mathematics, cipher decoding, analogies, practical items and other items in a time-limit of 45 minutes.

By the year 1947, the Group test had already been validated, initially by a sample of 1000 students from the SMS1932, and later on by a further 873 students from the same cohort (Deary, Whalley & Starr, 2009). The reason for the additional sample was because the first group had higher scores than the average. All of these students, who were individually tested on the Stanford Revision of the Binet-Simon Test, scored an average of 100 IQ points (Macmeeken, 1939). In total, 70,805 children sat the Group test in 1947.

Along with the MHT, a short sociological survey was also administered to all twins and children born on one of the first three days of each month. This survey included questions such as the child's height and weight, medical history, school attendance and family background. The sample that completed the long version is also known as the *36-Day Sample*. This consisted of approximately 7,000 children. A further sub-sample (n = 1,215) of the 36-Day Sample, consisting of children born on 1st day of the even numbered months, was gathered to individually test the children by trained people, and administer further testing to validate the MHT. This was known as the *6-*

Day Sample. This sample was followed up for 11 years up until 1954 with a report entitled, *Eleven-Year-Olds Grow Up*, and again after 16 years in 1963, with a report entitled, *Sixteen Years On*.

2.2 Results from the Scottish Mental Survey 1947

Children scored an average of 2.2 higher IQ points in the SMS1947 than the SMS1932, with girls contributing to the majority of the higher scores (Scottish Council for Research in Education, 1949). Results from the social survey found positive associations between favourable conditions at home and IQ. There were also associations with the father's social class, the occupancy rate of the home, and the mother's age. Results also looked at associations between geographical areas and IQ, in which the East and Southern areas of Scotland showed higher mental ability than the West and Northern parts (Scottish Council for Research in Education, 1958). Results showed associations between career and mental ability at age 11, home occupancy rate and mental ability, completing secondary school and mental ability (MacPherson, 1958, Maxwell, 1969). Indeed,

> The high score is likely to come from a family of one, two, or three, his father's occupational class is not likely to be lower than that of a skilled tradesman, his home will probably have occupancy rate 1 or 2 and there is a slightly greater chance of his being in a city. By the age of eleven he will almost certainly be in the last or last but one class in the primary school and is most likely to be selected for a five- year secondary school course in which he will be very happy…He is likely to complete at least five years in the secondary school and on leaving has a fifty-fifty chance of commencing training for a profession (MacPherson, 1958, p.158).

This result was further echoed in the 16- year follow-up:

> The three factors, education, occupational class and intelligence, are closely connected. The pupil of high IQ, for instance, is much more likely to continue some form of higher education, if his father is

> professionally qualified than the pupil of the same level of IQ, whose father is a manual worker. No one of the three factors is independent of the others, and selection by one, length of education for example, implies selection by the others (Maxwell, 1969, p. 184).

The SMS1947, along with its predecessor, the SMS1932, makes Scotland the only country in the world that has tested a nation-wide cohort (Scottish Council for Research in Education, 1949; Deary, Whiteman, Starr, Whalley & Fox, 2004).

2.3 The Lothian Birth Cohort 1936

Although the Scottish Council for Research in Education were aware of the data, it was stored away until Lawrence Whalley from the University of Aberdeen and Ian Deary from the University of Edinburgh rediscovered it in 1997 and realised the great potential it carried in exploring a whole new field of study of lifetime cognitive change - cognitive epidemiology (Whalley, Deary & Starr, 2009). No other country has ever tested the IQ of a whole nation let alone estimated lifelong cognitive change 60 years later. Indeed the monograph of the SMS1947 states that, “it is of utmost importance to society to know what happens to individuals with varying degrees of intelligence.” (Scottish Council for Research in Education, 1949, p. 149). The aim of the Lothian Birth Cohort 1936 is in fact to thoroughly investigate biological and psychosocial factors that are associated with cognitive ageing in these cohorts:

> [to] determine whether any associations existed between childhood IQ and the likelihood of surviving to old age… [to] determine whether any associations existed between childhood IQ and mortality and morbidity. (Deary, Whalley & Starr, 2009, p43).

The Lothian Birth Cohort 1936 consists of some of the surviving individuals who sat the SMS1947 and now live in the Lothian area, mostly Edinburgh, in Scotland. There are a total of 1091 participants (548 males, 543 females) who were traced and tested for baseline measures at 70 years of age. Their mean education is 10.7 years (SD = 1.13) ranging from 7 to 14 years. Investigations in this cohort span from brain imaging analyses, to genetic analyses, to cognitive testing (including the MHT), and interviews that gathered psychological and social data. The study is still on-going, collecting data every 3 years.

2.4 LBC1936 Testing Procedures

Individuals from the LBC1936 were traced through registrations with general medical practitioners. This was done with the permission of the Director of Public Health for Lothian, and under the ethical permission of the Multi-Centre Research Ethics Committee of Scotland, and from the Lothian Research Ethics Committee. The research was also carried out in accordance with the Helsinki Declaration (Deary et al., 2007). Media advertisements were also used to target individuals who may have been missed by the procedure but were still interested in participating. The study timeline can be seen in Figure 2.1.

Participants were tested in 2007 by two researchers at the Wellcome Trust Clinical Research Facility at the Western General Hospital in Edinburgh. The procedure included testing for cognitive and physical measures as well as other social information with 15-minute breaks for refreshments (Deary et al., 2007). The measures that are described below are only the ones that are used in this thesis.

2.5 The Lothian Birth Cohort 1936 Cognitive Battery

Table 2.1 illustrates the descriptive statistics of all the variables used in this study for the whole LBC1936 sample.

2.5.1 Cognitive Ability measures

2.5.1.1 Moray House Test

The Moray House Test (MHT) was re-administered when the participants were 70 years old under the same conditions. The test requires numeracy and literacy to complete it. It was developed by G. H. Thompson and his colleagues at the Moray House teacher-training centre. It is scored out of 75, and has a 45-minute time limit. The precise instructions of the test are found at the Scottish Council for Research in Education (SCRE, 1933, pp. 127-129). The test consists of questions relating to following directions, same-opposites, word- classification, analogies, practical items, reasoning, proverbs, arithmetic, spatial items, mixed sentences, cypher decoding and other items. The only 2 things that were changed for the retesting were because the questions had become outdated. These are:

- If 19 inches are the same as 1 foot and 7 inches write G, if not write R, which replaced, If 19d is the same as 1/7 write G, if not write R.

- Underline the ONE of the four correct answers to each statement which seems to you to be correct: Vitamine is found in (fresh milk and fruits, lard, dried fruits, stale bread). "Vitamine is" was replaced by "vitamins are".

To validate the test, 1000 pupils (500 boys and 500 girls), drawn from a broad geographical distribution across Scotland, were individually tested on the Stanford

Revision of the Binet-Simon test, with appropriate modifications from American terms to British adjustments. These later become known as the Binet 1000, and their birthdays fell either in June, May, April or July, although 6 of the children had their birthday in another month. Instructions to the printers of the test were sent detailing dates of distribution of the parcels. The testers, who did the work for free, were given instructions for testing in Edinburgh or Glasgow. The aim of this survey was to test the intelligence of Scottish students cross-nationally (Scottish Council for Research in Education, 1933). Although the pupils scored higher than average, both sexes had a mean of approximately 100. Due to the high scores, and the different testers, which may have reduced reliability, another sample was chosen to contribute to the validation of the MHT (the validation coefficient was likely to be on average above 0.8) (Deary, Whalley & Starr, 2009). Children born on the first day of February, May, August or November, of the year 1926, were tested under the same procedures. 873 children sat for the test. The results were similar to the SMS1932, with a mean of 100 IQ points (Macmeeken, 1939). The MHT from the SMS1947 sample was again revalidated by testing children from the same cohort born on the first days of even numbered months. This is known as the *6-Day Sample*. The test used to validate the MHT was the Form L of the Terman-Merrill revision of the Stanford-Binet Scale. This required the individual testing of 1,215 pupils. The correlation between the two tests was .81 for both sexes (Scottish Council for Research in Education, 1949, p.123). The MHT scores were then converted to IQ points using a mean of 100 and a standard deviation of 15 points.

2.5.1.2 Wechsler Adult Intelligence Scales

The Wechsler Adult Intelligence Scales (WAIS-III^{UK}) are a psychometric tool consisting of several subtests each measuring a different part of intelligence. They consist of three main composite IQ scores: Verbal IQ, Performance IQ, and Full Scale IQ; and four Index scores: Processing Speed, Working Memory, Perceptual Organisation, and Verbal Comprehension (Wechsler, 1997). The tests analysed in this study fall under composites of Verbal and Performance IQ, and indices of Processing

Speed, Working Memory, and Perceptual Organisation. Six subtests from Wechsler Adult Intelligent Scales (WAIS-III^{UK}) were analysed in this study. These subtests are listed below.

Letter-Number Sequencing. This subtest is an index of working memory. The participant listens to a series of randomly presented numbers and letters, and is then asked to repeat first the numbers, then the letters in a chronological order without forgetting any of them. Each item has three trials. The test stops once the participant fails to recall correctly all three trials.

Digit-Span Backwards. This is an index of working memory performance and falls under the composite of verbal IQ. This subtest measures working memory performance. The participant listens to a sequence of digits and repeats them in a backward order. A digit is added to the sequence after every successful trial. Testing ends when the participant fails two trials in a row.

Matrix Reasoning. This test is an index of perceptual organisation and a measure of non-verbal abstract reasoning. The subtest consists of 26 items. Each item consists of a matrix with pictures, which has a missing section, and five response choices. The participant selects the response that he thinks best fits the missing section. An example of this can be seen in Figure 2.2. The test is untimed, which makes it more suitable for older adults with slower response speed. After four consecutive incorrect responses the test is stopped.

Block Design. This is an index of perceptual organisation and a composite of Performance IQ. The subtest measures visuospatial ability and abstract reasoning. It consists of a set of 13 printed geometric patterns, and the participant is required to replicate the patterns using two-colour cubes in a limited time-period.

Symbol Search. This is an index of processing speed, and a composite of Performance IQ. In this subtest, the participant is presented with two sets of symbols, a target group consisting of two symbols, and a search group consisting of five symbols. The participant then has to point out which, if any, of the search group symbols, match the symbols in the target group as quickly as possible. An example can be seen in Figure 2.3. There is a time limit of 120s, and the number of correct responses determines the score.

Digit Symbol Coding. This is an index of processing speed, and a composite of Performance IQ. The participant copies symbols under the corresponding numbers using a key found at the top of the page. There is a 120 second time limit. The number of symbols drawn determines the score.

2.5.1.3 Wechsler Memory Scales

The Wechsler Memory Scales (WMS III^{UK}, 1997) is a battery of 11 subtests measuring learning, memory and working memory. It contains 6 primary subtests and 5 optional subtests. Four sub-tests from the WMS III were analysed in this study. These are the following.

Logical Memory I. This subtest measures immediate declarative memory. Two different stories are read to the participant, and after each story the participant immediately recalls it from memory. Scores are given on the accuracy of the retelling of the story, and on the recall of the themes.

Logical Memory II. This subtest measures delayed declarative memory. It is administered 25-30 minutes after Logical Memory 1. The participant is asked to recall both stories from memory. Scores are given on the accuracy of the recall.

Verbal Paired Associates I. Immediate declarative memory is also assessed in this subtest. The participant is read a list of eight pairs of words. After the whole list is read, the participant is read the first word of each pair, and asked to recall the second word from memory. The eight pairs of words are given in four trials but in differing order.

Verbal Paired Associates II. This subtest measures delayed declarative memory. It is given after 25-30 minutes of the administration of the Verbal Paired Associates I. The participant is read only the first word of each pair administered earlier. He has to recall from memory the corresponding word. Scores are given depending on accuracy.

Spatial Span. This subtests measures visual memory. The participant is asked to repeat a number of tapping sequences, with the sequences getting longer with every trial. This contains both a forward and a backward sequence. This study makes use of the overall total score.

2.5.1.4 Processing speed

Processing speed is measured by basic motor-movement responses. In this study three measures of chronometric speed were analysed. These are listed below.

Simple reaction time. The tool used for this procedure was constructed for the Health and Lifestyle Survey (1993). This involves a shallow rectangular box (Figure 2.4), which has a Liquid Crystal Display (LED) screen on the top. There are five numbered response keys arranged in an arc from left to right. These are labelled, 1, 2, 0, 3, 4. In this task, the participant rests his index finger of his preferred hand on the key numbered 0. As soon as the 0 appears on the LED screen, the participant presses the 0 button as quickly as possible. There are 8 practise trials, and 20 test trials with an interval between 1 and 3 seconds between the participant's response and the next stimulus' onset. The mean and standard deviation of the 20 test trials are then calculated (Deary et al., 2007).

Four-choice reaction time. The same tool as that used in the simple-reaction time is used in this task. The participant here rests his index and middle fingers of his left and right hands on the keys marked, 1, 2, and 3, 4 respectively. The participant presses the key corresponding to the figure that appears on the LED screen as quickly as possible. Each of the figures appears ten times in a randomised fashion. There are 8 practice trials and 40 test trials. The mean and standard deviation of correct and incorrect trials are then calculated separately (Deary et al., 2007).

Visual inspection time. This task assesses speed of visual processing. It involves the presentation of two parallel vertical stimuli of different length on a computer screen. One of the stimuli is 2.5cm long and the other is 5cm long. They are held together by a horizontal 2.5cm crossbar at the top. A backward mask is then presented. This involves a mix of 1.6mm wide vertical line, which overwrites the previous stimuli. A tiny fixation cross in the middle of the screen is presented for 500ms before the stimulus, and a blank interval of 800ms follows between the cross and the stimulus presentation. Participants sit comfortably with their eyes approximately 75cm away from the computer. They are then required to discriminate between two stimuli after the backward masking by clicking 1 or 2 depending which line they think was the longer. Figure 2.5 illustrates this. Although there is no time pressure to decide, the stimulus is only presented briefly. Ten trials of 15 durations at 6, 12, 19, 25, 31, 37, 44, 50, 62, 75 87, 100, 125, 150, and 200ms are presented. Scores are measured by plotting the duration of the stimulus against the accuracy. The computer program E-Prime (Psychology Software Tools, Pittsburgh, PA) was used to construct, run and analyse the task. The computer screen was running at a 160Hz refresh rate (Deary et al., 2007).

2.5.2 Psychosocial Wellbeing measures

2.5.2.1 Physical functioning

Level of physical activity. Participants were assessed on a 6-point scale of intensity varying from activity relating to household chores to strenuous exercise for more than twenty minutes at a time per month. A higher figure indicated higher intensity.

*Total number of days active per month***.** Participants were asked how many days per month they engaged in vigorous exercise that lasted for more than 20 minutes at a time, such as cardio- or circuit-based activities. A higher figure indicated higher levels of activity.

Activities of daily living. The Townsend's scale (Townsend, 1979) is a 9-item scale that assesses ability to perform activities of daily living involved in personal hygiene, getting dressed, eating independently, and being mobile, with answers ranging from 'yes, with no difficulty', to 'yes, with some difficulty', and 'no, needs help', with scores of 0, 1, and 2 respectively.

2.5.2.2 Emotional wellbeing

*Hospital Anxiety and Depression Scales***.** Participants completed the Hospital Anxiety and Depression Scales (HADS) (Zigmond & Snaith, 1983). This assesses recently prevailing emotional states. There are seven items for anxiety and seven items for depression, with scores ranging from 0 to 3 per item, and 0 to 21 per subscale. Higher scores signify greater anxiety and depression.

2.5.2.3 Quality of life

Quality of Life (WHOQOL-BREF) Assessment. Participants completed the brief version of the World Health Organisation Quality of Life (WHOQOL-BREF) Assessment (WHOQOL Group, 1998). This measures quality of life in four subscales covering physical, psychological, social, and environmental domains. There are 26 questions in all. All items are measured on a five-point scale, with higher scores denoting better quality of life. This questionnaire has good validity, reliability and consistency, and is applicable cross-culturally (WHOQOL Group, 1998).

2.5.3 Physical Fitness measures

2.5.3.1 Physical Fitness

Grip strength. This was measured for both left and right hands using a North Coast Hydraulic Hand Dynamometer (JAMAR). The best of three in each hand was recorded.

6-metre walk- time. Participants were asked to walk the length of 6 meters at a normal pace. The time taken to walk the distance was their score.

Forced Expiratory Volume in 1 second. This was calculated using the best score of three trials using a Micro Medical Spirometer

2.5.3.2 Inflammation

C-Reactive Protein. A blood sample was taken. The examination to measure CRP was performed using a dry slide immuno-rate method on the OrthoFusion 5.1 F.S. analyzers.

Neutrophil Count. A blood sample was taken to also estimate the neutrophil count using a LH50 Beckman Coulter instrument.

Fibrinogen. This measure was taken from a blood sample taken from the participants, by using an automated Clauss assay (TOPS coagulometer, Instumentation Laboratory, Warrington, UK).

2.5.3.3 Morbidity

Participants were interviewed for their medical history, and were asked if they had histories of high blood pressure, diabetes, high cholesterol, cardiovascular disease, leg pain, blood circulation problems, stroke, cancer, thyroid, Parkinson's disease, arthritis, gout, or any other disease that had not been mentioned. Participants were also asked to name all medications they were taking at the time.

2.5.4 External variables

Variables that helped in describing how the groups differed from each other on variables other than those used to form the groups were referred to as external variables. These included demographic measures, personality measures and health behaviour measures. These are described in more detail next.

2.5.4.1 Demographic measures

These included: self-reported total number of years in formal education; marital status (i.e., single, married, widowed, separated, or divorced); living status (i.e., alone or not alone); and the person's own highest professional social class during working life. This was based on Her Majesty's Stationary Office (HMSO, 1980) rankings, ranging from I, which is the professional social class, up to V, which is the most manual class, with class III being divided into III-N (non-manual) and III-M (manual) (Office for Population Censuses and Surveys, 1980). For females, husband's social class was used when higher.

2.5.4.2 Prior cognitive ability

The *Moray House Test No. 12* (Scottish Council for Research in Education, SCRE, 1933; 1949), was administered when participants were aged about 11 years, on 4th June 1947 in the Scottish Mental Survey 1947. It is a group-administered test of general cognitive ability that included items measuring the ability to follow directions, same-opposites, word classification, analogies, practical items, reasoning, proverbs, arithmetic, spatial items, mixed sentences, cipher-decoding, and others. More detail on this in Section 2.5.3.1.

The National Adult Reading Test (NART) (Nelson & Willison, 1991) is a widely-used test to estimate prior cognitive ability. It requires the participant to pronounce 50 irregular English words.

2.5.4.3 Personality measures

Participants completed the *NEO- Five Factor Inventory* (Costa & McCrae, 1992), which is a 60-item inventory assessing the five major personality factors: Neuroticism, Extraversion, Openness to experience, Agreeableness, and Conscientiousness. Neuroticism measures emotional stability, such as anxiety, depression, and self-consciousness. Extraversion measures levels of sociability, such as time spent with others and ease of talking to people. Openness to experience measures the willingness to entertain novel ideas and immerse oneself in new situations. Agreeableness measures interpersonal dynamics, such as levels of sensitivity, empathy, and altruism. Conscientiousness measures self-discipline and self-control. The NEO has shown to have high internal consistency of the facet scales, with coefficient alphas ranging from .86 to .92 (Costa & McCrae, 1992). Participants rated themselves on each item on a five-point likert-scale, ranging from strongly disagree, to disagree, neither agree not disagree, agree to strongly agree, depending on how well they thought the statement described them.

2.5.4.4 General health measures

Participants were given a physical examination, which included: time to walk 6 meters; mean grip-strength of both left and right hands using a North Coast Hydraulic Hand Dynamometer (JAMAR); best of three in forced expiratory volume in 1 second (FEV_1) and forced vital capacity (FVC) using a Micro Medical Spirometer; and body mass index (BMI) using a SECA stadiometer to measure height (in cm) and electronic SECA digital scales to measure weight (in kg), and then dividing weight (kg) by height squared (m^2) to get the BMI. Participants were also asked about total units of alcohol consumed per week as measured by the Food Frequency Questionnaire (FFQ) version 7.0. Participants were asked whether they currently smoked, had quit smoking, or never smoked (smoking status).

2.5.4.5 *APOE* e4 allele

For the *APOE* e4 allele, known to be associated with cognitive function in older adults (Deary et al., 2002), genomic DNA was isolated from whole blood. Two polymorphic sites (rs7412 and rs429358) that account for the e2, e3, and e4 alleles (Wenham, Price, & Blandall, 1991) were genotyped with TaqMan technology by the Wellcome Trust Clinical Research Facility Genetics Core, Western General Hospital, Edinburgh. Three readings of each of both sitting and standing systolic and diastolic blood pressure were taken using an Omron 7051T monitor as part of the physical exam. The average of each of the readings was used.

When investigating specific domains of wellbeing, e.g. the Cognitive Ability domain, other variables that were used to form components for other domains, e.g. physical functioning, emotional wellbeing, and quality of life for Psychosocial

Wellbeing; were treated as external variables to help in describing thoroughly any group differences.

2.6 Statistical techniques

This study made use of three main statistical techniques – principal components analysis (PCA), cluster analysis (CA), and latent class analysis (LCA). PCA was used to extract components from cognitive measures, psychosocial measures, and physical measures of wellbeing domains. CA and LCA were used to group together individuals who showed similar scores on measures of cognitive, psychosocial and physical function. Exploring and identifying relevant statistical techniques that could be applied, and ultimately deciding on a more suitable one in reaching the study's goals, were other aims in using different techniques. These techniques will first be described in some detail before moving onto the next section, which describes the procedure used in this study.

2.6.1 Principal components analysis

Principal components analysis (PCA) is a statistical data-reduction technique that identifies groups of variables that are associated and transforms them into a set of linearly uncorrelated constructs. It is used for three main purposes: to make sense of a set of variables; to construct questionnaires; and to summarise the common features of data along a small number of identifiable dimensions (Field, 2004). In order to achieve these purposes, new variables called principal components, are computed. In PCA all variance in the observed variables is accounted for - the first component accounts for the largest variance in the observed variables, the second accounts for the largest variance that was not accounted for by the first component, and so forth until all variance in the data has been accounted for. PCA explains maximum variance in the minimum number of constructs (Field, 2004). It uses both oblique and orthogonal transformation. The number of components in PCA is typically determined by the use of Eigenvalues and through inspection of the scree slope. The component explaining the greatest amount of variance is the first principal component

(Watson and Thompson, 2006). The number of components derived from PCA should be meaningful: a result of both mathematical techniques and intuition (Watson and Thompson, 2006). PCA mainly differs from the commonly used factor analysis (FA) in that it uses all the variance in the variables to create components (as opposed to just the variance that is common amongst the variables). In this study PCA was used to summarise common features of the data to identify components of cognitive, psychosocial and physical function.

2.6.2 Cluster Analysis

Cluster analysis is a type of data mining technique that seeks out patterns in the data. It identifies and clusters homogeneous groups of individuals based on the similarity of their responses, creating within-group similarity and between-group segregation (Aldenderfer & Blashfield, 1984). This technique was first developed by two biologists, Robert Sokal and Peter Sneath in 1963, and discussed in their book entitled *Principals of Numerical Taxonomy*.

Various clustering algorithms exist. In this study I used hierarchal clustering, which is based on connectivity models to build hierarchal clusters based on measures of distance; and K-means clustering (also known as partitioning since it partitions the data on an *a priori* set of clusters), which is based on centroid models to build clusters based on a central vector. I used both techniques because I did not know *a priori* whether the data contained hierarchical clusters of individuals or distinct separable groups.

Hierarchal clustering procedures operate in a stepwise manner to connect 'data points' to form clusters based on their distance. The algorithm builds a hierarchy of clusters represented by a dendrogram, which is a tree-like diagram illustrating the clusters that could be likened to the branches of a tree. Hierarchal clustering can be agglomerative (each case starts as its own cluster) or divisive (all cases start out as one cluster). An example of a dendrogram can be seen in Figure 2.6. The dendrogram provides a hierarchy of clusters that form at several distances. There are several distance measures within hierarchal-based clustering, each of which has different linkage criteria. For example, single-linkage (nearest neighbour approach) is based on a defined minimum distance amongst cases containing the same level of similarity, in complete-linkage (farthest neighbour approach) a case has to be similar to all members of a cluster for it to be added, and average-linkage is based on the cluster's average and the cases' similarity to that average. The key limitation with these approaches is that outliers in the data affect them. Ward's method is another distance measure, which attempts to minimise the sums of squares of any two clusters by using analysis of variance. Although it is efficient, it tends to create small clusters.

K-means clustering is a non-hierarchal partitioning technique usually performed after hierarchical procedures. Unlike other clustering methods it employs least square partitioning in an *a priori* fixed number of clusters. Clusters are represented by a central mean – K-means finds these cluster centres and assigns cases to the nearest mean. The centre is updated every time a new case joins the cluster until the cluster centres do not change. The algorithm is based on Euclidean distance to measure cluster variance. Euclidean distance can be squared to place weight on cases that are further apart. A key limitation of *K*-means clustering is that the number of clusters has to be specified *ad-hoc*, where an unsuitable choice of clusters may inevitably produce poor results. Furthermore, the model assumes that the specified clusters are of the same size so cases are assigned to the nearest centroid with the largest possible distinction amongst the clusters, running the risk of incorrectly separating data points and assigning otherwise similar cases into separate groups (Vermunt & Magidson, 2002; Magidson & Vermunt, 2002).

The final result typically requires some sort of validation, which helps in establishing internal consistency and external validity to verify or nullify the results obtained (Aldenderfer and Blashfield, 1984; Hair et al., 1998). The present study makes use of replication and ANOVA on external variables. Here only a brief description about them is given, the procedure on how they were applied in this study is given in Section 2.7 (*Procedure*).

Replication. If a cluster solution is highly replicable across a number of different samples, the solution is considered to have generality. Replication can be done by running the analysis several times using various clustering criteria i.e. for one analysis using the whole sample, and then splitting it up in half to find out if the halves replicate each other and the whole sample. By using different algorithms, the researcher can explore the mathematical robustness of the solution. However, in establishing validity, replication is a necessary but not sufficient condition since replicable cluster solutions do not necessarily mean they are a valid result (Aldenderfer and Blashfield, 1984).

Carrying out tests on external variables. Aldenderfer and Blasfield (1984) proposed this method as the best available for external validation purposes. This method directly tests the generalisation of a cluster solution by using variables that were not included in the clustering process but are related to the subject of study. By using external variables as dependent variables (and cluster groups as independent variables) in ANOVA procedures, the researcher finds out if , and how, the clusters differ from each other. Hair et al., (1998) call this profiling, which can be used to get a clearer picture of the clusters. The value of a cluster solution that shows external validation is greater than a solution that does not. However, unless external variables have been available but held back from the cluster analysis, this procedure may be expensive, as it would require more data collection. It may also be difficult to know at initial stages of the study which set of external criteria may be relevant *a priori*. Cluster analysis by its very nature divides entities, even if the data are continuous; it is within the scope of ANOVA to find differences among groups. Thus the results ANOVA gives make this method seem attractive to verify internal consistency from cluster analysis; however, it could be misleading if cluster solutions have been forced onto the dataset.

There are a lot of clustering techniques that employ specific methods of combining cases, a lot of validation techniques that can be categorised by purpose, and a lot of subjective judgments that need to be taken. All of these have their relative strengths and limitations, which are important to be aware of when deciding upon which methods to employ. Ultimately, determining the number of clusters involves a process in which the researcher carries out the difficult task of choosing between parsimony (less homogeneity) and similarity (more clusters) (Hair et al., 1998). It is also a subjective process since the initial identification of the number of clusters is mainly dependent on the dendrogram, which offers no statistical material to justify retaining a certain number of clusters over another. K-means offers no probabilistic models of membership classification either. Because cluster analysis is not based on *a priori* knowledge, it makes necessary additional validation methods that may help in justifying the final cluster-solution.

2.6.3 Latent Class Analysis

Latent class analysis (LCA) is a latent general mixture modelling (GMM, models with a mixture of probability distributions where each latent class represents a hidden group, McLachlan & Basford, 1988) technique, typically used to identify the presence of sub-populations with qualitative and categorical differences within an overall population. It explains empirical associations among observed variables using a measurement model where the observed variables that define the latent groups are specified. This technique was initially termed *latent structure analysis* by Lazarsfeld (1950), to describe the use of mathematical models that represent latent variables in survey research (Henry, 1983).

The latent class model can be seen as a model-based or a probabilistic variant of non-hierarchal clustering techniques, such as K-means. Although it is primarily intended for qualitative and categorical outcomes (McCuthcheon, 1987) it *can* also be used as a probabilistic cluster analysis tool for continuous data (Nermunt & Magidson, 2001; McLachlan & Peel, 2000). Typically, when the latent variable is categorical, and the observed variables are continuous, the procedure is referred to as latent profile analysis; however, the term is infrequently used and often used interchangeably with the term LCA, since the underlying assumptions (i.e. the population containing a latent number of unobserved groups) are the same. Although technically my study would be classified as LPA (due to the continuous manifest variables) I refer to all analyses as LCA, to keep to its original and mostly used term.

This technique is similar to factor analysis, but instead of grouping together variables, LCA groups together cases. Cases are grouped into classes by conditional probability estimates – these give the probabilities of the class each participant is likely to fall in depending on the scores on the observant variables. These help in naming the groups depending on how they differ from each other.

The typical LCA model holds by the following equation,

$$f(\mathrm{y}) = \sum_{i=0}^{n} P(x)\, f(\mathrm{y}|\mu_x, \textstyle\sum_x),$$

where $f(\mathrm{y})$ denotes a mixture of class-specific densities. Each latent class is represented by x, which has its own mean vector μ_x and covariance matrix $\sum_x$. P(x) represents the number of individuals per group. In classic LCA this model assumes local independence, in which the manifest variables are assumed to be independent of each other within the latent classes (therefore the latent trait explains the association amongst the observed variables). This assumption is important because it identifies natural and useful groups (Lazarsfeld & Henry, 1986), and is formulated as,

$$f(\mathrm{y}) = \sum_{i=0}^{n} P(x) \prod_{\ell=}^{L} f(y\ell|\mu_1 x^{1}{}_{\ell}, \sigma^2_{\ell x}),$$

where $\sigma^2_{\ell x}$ assumes local independence. If the assumption of local independence is violated (i.e. some variables are correlated), results may give high model fit indices, which may lead the researcher into adding more latent classes to fit the data. However, recent methods allow the relaxation of the local independence assumption for groups of associated variables, since previous methods have been too restrictive.

The parameter estimates of the latent class models are based on the concept of likelihood. This is a measure of probability of how close to the data the distribution lies by estimating various alternatives for the mean of the population (μ). In maximum likelihood (ML) estimation, the values of the data's parameter estimates are linked to the distribution being studied to produce the greatest probability of the similarity of the distribution to the data. Parameters are estimated for the size and description of each group. Two main limitations of ML estimation in LC models are: the model parameters may result in non-identification, and there may be presence of local maxima. When non-identification occurs, a unique set of parameters is not found, while in the presence of local maxima, the model may converge to a different maximum depending on what the starting values were. Vermunt and Magidson (2001) suggest using different starting values to deal with either of both cases. In the case of non-identification, the identified model gives the same final estimates for every new set of starting values, whilst for local maxima, the few sets that converge to same highest log-likelihood are typically the ML solution. ML, however, relies on the assumption that the data are normally distributed – non-normal distributions may give the impression of heterogeneity within the data, and may give rise to latent classes that do not actually exist. This may consequently reduce power to identify correlations of classes and external variables (Bauer & Curran, 2003).

Popular model-selection measures in LCA are information criteria such as, the Bayesian Information Criterion (BIC; Raftery, 1995), the Akaike Information Criterion (AIC; Akaike, 1983), and the adjusted BIC (adjBIC; Sclove, 1987). These are based on the likelihood function estimate, favouring models that are closer to the representation of the data. They help in identifying better-fitting models among various alternatives. Typically these fit indices prefer models with fewer classes, and the solution that minimizes the AIC/BIC, is the best fitting one (Bauer & Curran, 2003). However, this is not always the case – these indices do not always clearly suggest one best-fitting model, and typically with continuous data, the more latent groups there are the better the fit (Johnson & Bouchard, 2008). Here the researcher would need to find a balance between parsimony and fit.

Entropy (ENT) is another measure that helps in finding a suitable solution. It is used to indicate how well the variables predict group membership (Celeux & Soromenho, 1996). In LCA entropy is defined on a 0 to 1 range with values closer to 1 indicating a higher degree of certainty in membership classification, and values closer to 0 indicating lower certainty. Thus the closer to 1 the entropy is, the better defined the groups are.

Since LCA provides measures of goodness-of-fit for models, unlike other classification techniques, such as cluster analysis, it can be used to test formally whether the data are best described in terms of a number of discrete classes, and how many classes optimally describe the data. A look at the probability variables will give good information on which individuals belong to which class. Once the number of latent classes is settled, the next step is to describe the profiles of the classes.

LCA and CA are similar in that both are useful data-reduction techniques that construct groups based on minimising within-group homogeneity and maximising between-group heterogeneity (Green, 1951, 1952). Both are classified as unsupervised learning techniques since the number of clusters/classes is unknown and has to be pre-specified. However, LCA offers many advantages over traditional cluster analysis techniques (Vermunt & Magidson, 2002). Firstly, LCA uses rigorous statistical procedures, rather than mathematical methodologies. These include assigning model-based posterior probability for classification of cases, which is estimated by ML, to provide misclassification estimates, as opposed to measuring distances to cluster centres using linear algebra (e.g. Euclidian distance to measure similarity). LCA also provides various diagnostic techniques (such as the Bayesian Information Criterion, log-likelihood, and p-values) to determine optimal number of groups and the significance of the variables; CA offers no assistance in determining the cluster solution. LCA also allows unstandardized variables, and allows external variables (such as demographics or personality measures) in the model. An advantage of using a statistical approach for class-selection is that the final choice is based on a more informed decision of rigorous testing.

2.7 Procedure

In this section I give an account of the procedure of how the analysis developed and proceeded throughout the study. Here I describe some general results from the study that may help in providing a background as to how I made use of the statistical techniques of PCA, CA and LCA. The purpose of this brief account is to provide a guide of how the thesis unfolds.

Firstly, to form components of domains of wellbeing, specifically domains of cognitive functioning, psychosocial wellbeing, and physical fitness, principal components analysis was applied. Secondly, to explore the possibility of subgroups of individuals within these components, two techniques were employed: cluster analysis and latent class analysis. The aim of using two techniques was to explore which suited the data and aims of this study better. The procedure used to extract components of wellbeing, and analyse and classify this sample is described next.

2.7.1 Formation of the Components of the Domains of Cognitive, Psychosocial and Physical Wellbeing - Principal Components Analysis

I used principal components analysis to extract principal components for domains of Cognitive Functioning, Psychosocial Wellbeing, and Physical Fitness in order to reduce the number of variables entered into the latent class analysis. Three components emerged for each of the domains of Cognitive Ability, Psychosocial Wellbeing, and Physical Fitness. In this section a list of the variables used to make up each of the components of these domains is presented. Table 2.2 shows a summary of the constituents of the domains and components of wellbeing used in this thesis. A thorough description of these variables has already been presented in Section 2.5 of this chapter.

Although PCA was the main technique used to create components I applied FA to create the general cognitive ability factor (*g*) since studies show that PCA inflates the influence of the general factor loadings. Authors have established that to develop *g* specifically, FA should be chosen over PCA (Floyd, Shands, Rafael, et al., 2009; Thorndike, 1987). Therefore, for the Cognitive Ability domain, I extracted a factor from FA for *g*, and components from PCA for Memory and Speed variables. From now onwards, however, I refer to all derived outcomes as components for simplicity. Variables constituting *g* included six subtests from the Wechsler Adult Intelligence Scales (WAIS, Wechsler, 1997), specifically Symbol Search, Digit Symbol Coding, Matrix Reasoning, Digit Span Backwards, Letter Number Sequencing, and Block Design. For the Memory component, variables included four subtests from the Wechsler Memory Scales (WMS, Wechsler, 1999), specifically Logical Memory I, Logical Memory II, Verbal Paired Associates I (VPA I), and Verbal Paired Associates II (VPA II). For Speed, the measures included Simple Reaction Time, Choice Reaction Time, and Inspection Time.

For the Psychosocial Wellbeing domain, components representing Physical Functioning and Quality of Life (QOL) emerged. For the Physical component, the variables used included level of physical activity, number of days active per month, and activities of daily living (ADLs). The QOL component consisted of the four variables from the World Health Organisation Quality of Life (WHO-QOL) questionnaire, which included measures of physical, psychological, social, and environmental wellbeing. Another component, Emotional Wellbeing was also used; however, this component was extracted by generating the means for the 2 variables (one for anxiety symptomatology, and one for depression symptomatology) of the Hospital Anxiety and Depression Scales (HADS) since there were not enough variables for PCA. This variable was then reversed (by multiplying the scores by -1) so that a higher score indicated better emotional wellbeing.

For the Physical Fitness domain, components representing Physical Fitness and Lack of Inflammation emerged from PCA. For the Physical Fitness component the variables used included Grip Strength, Forced Expiratory Volume in one second (FEV_1), and 6-Metre Walk Time. Because these variables show strong sex differences and vary with body size, I used residuals after regression on sex and height. The inverse of the 6-Metre Walk Time variable was computed on SPSS. This was done so that higher scores could be equated with faster speed. This variable was then termed Gait Speed. Variables constituting the Inflammation component included C-Reactive Protein (CRP), Neutrophil Count, and Fibrinogen. These were then reversed (by multiplying them by -1) so that higher scores reflected better wellbeing. This component was then renamed Lack of Inflammation. Another subdomain, Lack of Morbidity was also used. Since only two variables were used for this component, the variables for total number of medical conditions, and total amount of medications taken, were standardised and their mean was calculated. This variable was also reversed, in order to equate higher scores with better wellbeing, and renamed Lack of Morbidity.

All of the components used in this study were standardised and analysed as z-scores (mean = 1, standard deviation = 0) throughout the whole study to avoid complications comparing results. Outlying component scores were trimmed to within 3 standard deviations of the means. This process avoided deleting cases that may have highlighted trends of low or high functioning subgroups, but simultaneously avoided extreme and likely spurious outliers that could have influenced the results. Standardisation helps in having all variables contribute equal amounts of distance. The resulting variables were basically normally distributed.

2.7.2 Formation and Classification of groups within the LBC1936 – Cluster Analysis and Latent Class Analysis

Cluster analysis and latent class analysis techniques were used as different group-generating methods to explore and compare results on just the first set of data that was explored, Cognitive Ability (Chapter 3), in order to understand their relative strengths and weaknesses first-hand in this context. The application of CA and LCA on the cognitive components is described next.

Cluster Analysis. To apply cluster analysis, the sample's standardised scores on measures of *g*, Memory, and Speed were split into two random sub-groups, the aim of which was to create two datasets that could be viewed as replication samples that could then be used to validate the cluster results. Ward's method (Ward, 1963) was chosen to minimise within-cluster variance. Euclidean squared distance was the distance measurement applied for assessment of similarity between cases. This was independently applied in each dataset. The dendograms from Ward's hierarchal method were then analysed to find out how many clusters these suggested.

Using the initial centroids obtained from the cluster analysis, a K-means iterative partitioning was used to confirm the stability of the cluster solutions as a validation technique. As required by K-means analysis, the number of clusters had to be pre-specified for it to assign cases into clusters and consequently finding the best cluster solution based on the assigned number.

To test the predictive validity of the derived cluster solution, a second K-means cluster analysis, with random initial seed points, was run. This was done because the starting point of the cluster seeds depends on how the data are ordered. By randomising initial seed points, the data are reordered, which may affect the results (Anderson & Black, 1998). Similar results provide evidence that the cluster solution is robust, which would add to the internal consistency of the cluster solution. The analysis was followed by analysis of variance (ANOVA) on external variables to test further the validity of the solution. A one-way ANOVA was conducted using two external variables, Age 70 IQ and Spatial Span, which were not included in the cluster solution. In this study, Age-70 IQ and Spatial Span were chosen as external variables because, like *g*, Memory and Speed, they are markers of cognition that reflect cognitive ageing. The Moray House Test No. 12 was used for the Age-70 IQ variable. Spatial Span, also a reflection of fluid cognition, was used to measure spatial learning and memory (Wechsler, 1997). Age-70 IQ and Spatial Span were included in the ANOVA as dependent variables, and the cluster membership as independent variables. This was performed to test for differences among the derived clusters on other measures of Cognitive Ability.

The final model was ultimately based on the degree of replication between the two sub-samples, parsimony, model-fit criteria, and the results of validation techniques, specifically the degree of convergent and divergent validity. Once the clusters were validated, a description of their profiles was attempted to explore how they differed from one another. LCA was then used to compare and possibly confirm results from CA. The procedure of this is described next.

Latent Class Analysis. LCA was first applied to scores on *g*, Memory and Speed to explore possible subgroups within the data. A number of model solutions ranging from 2 to 7 group solutions were defined for each domain of function. Due to the possibility of local (rather than global) maxima, 20 random starts were used in the initial stage and 10 optimisations in the final stage to get appropriate model convergence and to be confident of a robust solution since the default number of starts (10) and optimisations (5) provided by MPlus was insufficient to locate the model with the highest log-likelihood (Hipp & Bauer, 2006). Missing data were dealt with by using the ML estimation missing data feature in MPlus to include all participants. The results from these solutions were compared using the Akaike information criterion (AIC), the Bayesian information criterion (BIC), the adjusted BIC, and entropy. Solutions that included groups containing less than 5% of the population were avoided unless they had distinctive, theoretically meaningful qualities setting them aside from the rest of the groups, because groups of this size are more likely to have resulted from chance sample characteristics (Bauer & Curran, 2003). The most parsimonious solution was also sought. Each participant was assigned group membership based on the highest probability of belonging to a particular group. Because of the possibility that LCA would not reveal actual natural classes in these continuous data and thus had primarily practical and descriptive value, I refer to the results as 'groups' rather than 'classes' throughout. Also, in most cases the LCA produced a continuum of high-, average-, and low- scoring groups; however, I still refer to these as 'groups' throughout – the 'splitting' of the continuum served in providing a thorough description of the groups' characteristics in the cohort.

After using both techniques I found that LCA offered several advantages over CA. Firstly, the choice in the number of clusters from the dendrogram in the hierarchal agglomerative procedure was a matter of personal opinion (another researcher may have opted for a different number of clusters depending on how the tree-like branches described above are decided to be "cut"). As suggested by previous authors (Aldenderfer and Blashfield, 1984; Lazarsfeld & Henry, 1968) I then used three validation techniques (replication, non-hierarchal clustering and ANOVA on external variables) to help me in my decisions on the cluster solution I derived from the hierarchal analysis. In the K-means cluster analysis, which uses only an *ad hoc* approach, by inputting the numbers of groupings I considered appropriate from the hierarchal procedure. However, results from this provided no such statistical indices to help me decide on the number of groups in the data. With LCA, although also unsupervised, I specified various number of groups in the model, the results of which offered a posterior probability-based classification based on ML estimation methods, which also produced misclassification rates; and a range of model fit indices (BIC, AIC, adj. BIC, and ENT) to help me determine the number of groups. I thought it best to proceed with LCA since it seemed to provide a more reassuring way to proceed with the analyses. LCA was applied henceforth for the Psychosocial Wellbeing components, the Physical Fitness components, and all of the components representing all domains together. External variables were also used to explore any differences (using ANOVA) and predictors (using logistic regression) amongst the groups. Therefore, LCA, ANOVA and regression were the main analyses used in this study (more on ANOVA and regression below).

The LCA process as described above was then repeated with psychosocial measures, physical measures, and finally all cognitive, psychosocial and physical measures together.

In the final analysis (Chapter 7) I applied LCA to all measures of Cognitive Ability, Psychosocial Wellbeing, and Physical Fitness. This was the final and most important analysis of the thesis since I was applying an inclusive and multidimensional perspective to test the cohort on all domains of wellbeing simultaneously. I considered it important to find out if the solution replicated. To assess replicability I split the sample randomly in half and ran LCA on the two groups. Then, I tested whether the groups identified in the first subsample could be reproduced in the other half. Thus, participants in one of the subsample were considered to have known group membership based on the chosen model. This was used to predict membership for the other half of the participants by testing whether the new predicted membership differed from that originally generated by the LCA on this subsample itself. The criteria used to form the group solution in the first subsample were thus used to assign group membership in the second subsample, and these assignments were compared with those from the group solution generated in this sample. Using goodness-of-fit criteria (the Pearson's chi-square test), the differences between endogenously and exogenously generated group memberships were compared and tested.

The generated groups throughout the whole thesis, i.e. groups derived from cognitive ability, psychosocial wellbeing, physical fitness, and from all three domains studied together, were described according to their patterns of scores across the studied measures. External variables not used on the formation of the groups were also used to describe how the groups differed from each other. More on these is described next.

Associations with external variables. In all instances I first ran analyses of variance (ANOVAs) with group membership as the independent variable to describe how the groups differed from each other on external variables other than those that were used to form the latent groups. These external variables were used as dependent variables to test for differences amongst the groups identified. Post-hoc tests for significant findings using Tukey's Honestly Significant Difference (HSD) test comparisons in order to explore which groups differed significantly from the others were also applied. I then used multinomial logistic regression (MLR) analyses with group membership as the outcomes to explore whether any of the external variables predicted group membership for any of the generated groups. The largest group was used as the baseline group in all instances.

I used both ANOVAs and MLRs because I wanted to firstly determine the variables that distinguished amongst the groups (using ANOVAs which treat the groups as the independent variable) and secondly to determine which variables predicted group memberships (by using logistic regressions, which treat groups as the outcome). Thus ANOVAs helped in determining whether significant differences existed amongst the groups; MLRs helped in finding out whether external variables significantly predicted group membership; hence looking at both sides of the coin. MLRs also allowed analysis for the strength and direction group membership may have on external variables. The logistic regression *p*-values were also adjusted for multiple testing amongst variables using the Bonferroni correction in all instances. This test was developed by Dunn in 1961 to help in controlling for the family-wise error rate generated by testing for one hypothesis at a time when testing several variables simultaneously. This is done by correcting each individual test's Type 1 error rate (α) by dividing it by the total number of comparisons. It is a conservative test and may produce false negatives i.e. fail to indicate significance when present. The MLRs were included as an extension of the mean comparisons. Results should be consistent across methods; however, this was not always the case. ANOVA is a more powerful tool and does not assume order for categorical variables. Despite this, both techniques were meant to complement each other.

2.8 Statistical analyses

The Statistical Package for the Social Sciences (SPSS, version 17.0, SPSS Inc., Chicago, IL, USA) was used to carry out the formation of the cognitive, psychosocial and psychical components using PCA and FA; to classify the cohort on cognitive measures only using CA, and to run tests (ANOVAS) for the validation techniques used in this section. This program was also used to carry out tests using ANOVAs on the external variables, which are described above. Mplus (version 5.2, Muthen & Muthen, 2004) was used to carry out LCA using maximum likelihood estimation to identify groups of individuals who shared similar scores on cognitive, psychosocial, and physical components. Multinomial logistic regression analyses on the external variables were also run using MPlus. MPlus is a flexible statistical program that can be used for both cross-sectional and longitudinal data, as well as single and multi-level data, with latent and/or observed variables.

Table 2.1
Variable means (total number and percentages where indicated with a % sign in parentheses) for the Lothian Birth Cohort.

Variable	Participants' (n = 1091) means (standard deviations in parentheses)
Demographics	
Number of males (%)	548 (50.2)
Age 11 IQ	100 (15.0)
NART (range 0-50)	34.5 (8.2)
Yrs. Educ. (range 7-14 years)	10.7 (1.1)
Number married (%)	778 (71.3)
Number living alone (%)	266 (24.4)
Number in the professional social class (%)	190 (17.4)
Personality (range 0 – 60)	
Neuroticism	17.1 (7.6)
Extraversion	27.0 (5.9)
Openness	26.1 (5.8)
Agreeableness	33.5 (5.3)
Conscientiousness	34.7 (6.0)
Physical function, physical fitness and health (Range for each variable in parentheses)	
Grip strength (4-60kg)	27.5 (10.1)
6m walk time (1.05 – 14.74m)	3.9 (1.2)
FEV_1 (.49 – 5.13)	2.3 (0.7)
FVC (1.13– 6.93)	3.0 (0.9)
C-reactive protein (1.5 – 90.0)	5.3 (6.7)
Fibrinogen (1.6 – 6.2)	3.3 (0.6)
Neutophil (1.44 – 14.8)	4.4 (1.6)
Days active per month (0-31)	7.7 (8.1)
Level of physical activity (1.1-1.5)	3.0 (1.1)
ADLs (0-2)	1 (2.0)
BMI (16.02 - 48.52)	27.8 (4.4)
Units of alcohol/week (0-140)	10.6 (14.2)
Number of current smokers (%)	146 (13.4)
APOE e4 present (%)	306 (29.8)
Disease	
Number with high blood pressure (%)	433 (39.7)
Number with diabetes (%)	91 (8.3)
Number with CVD (%)	268 (24.6)
Number with blood circulation problems (%)	156 (14.3)
Number with history of stroke (%)	54 (4.9)

Total number of medications (0-8)	3.8 (2.6)
Total medical conditions (0-8)	3.8 (3.1)
Cognitive ability	
g (2.51-2.11)	.00 (.7)
Memory (-2.78-1.78)	.01 (.8)
Speed (-3.00 – 1.86)	.01 (.6)
Quality of Life (range: 5.33 – 20.00)	
Physical QOL	16.1 (2.6)
Psychological QOL	16.0 (1.8)
Social QOL	17.1 (2.4)
Environmental QOL	16.7 (1.8)
Emotional Wellbeing (range: 0 -17)	
HADS (Anxiety)	4.9 (3.2)
HADS (Depression)	2.8 (2.2)

Note. IQ =Intelligence Quotient. NART = National Adult Reading Test. Yrs Edu = Total number of years in formal education. FEV_1 = Forced expiatory volume in 1 second. FVC = Forced vital capacity. BMI = Body Mass Index. APOE e4 = Apolipoprotein E allele e4. CVD = cardiovascular disease. ADLs = Activities of Daily Living. HADS = Hospital Anxiety and Depression scales. QOL = Quality of Life. Higher scores denote better wellbeing, ADLs and HADS scores were reversed to equate a higher score with better wellbeing.

Table 2.2

The three main domains of wellbeing, their sub-components and the variables they were constituted from and the statistical tools used to derive them.

Domains	Components	Variables	Statistical tools
Cognitive Ability	General cognitive ability	Symbol search Digit symbol coding Matrix reasoning Digit span backwards Letter number sequencing Block design	Factor Analysis
	Memory	Logical memory I Logical memory II Verbal paired associates I Verbal paired associates II	Principal components analysis
	Speed	Simple reaction time Choice reaction time Inspection time	Principal components analysis
Psychosocial Wellbeing	Physical function	Level of physical activity Days active per month Activities of daily living	Principal components analysis
	Quality of life	Physical Psychological Social Environmental	Principal components analysis
	Emotional Wellbeing	HADS – Anxiety HADS - Depression	Means
Physical Fitness	Physical fitness	Grip strength Forced Expiratory Volume 6-metre walk-time	Principal components analysis
	Inflammation	C-Reactive Protein Neutrophil count Fibrinogen	Principal components analysis
	Morbidity	Total number of medical conditions Total number of medications	Means

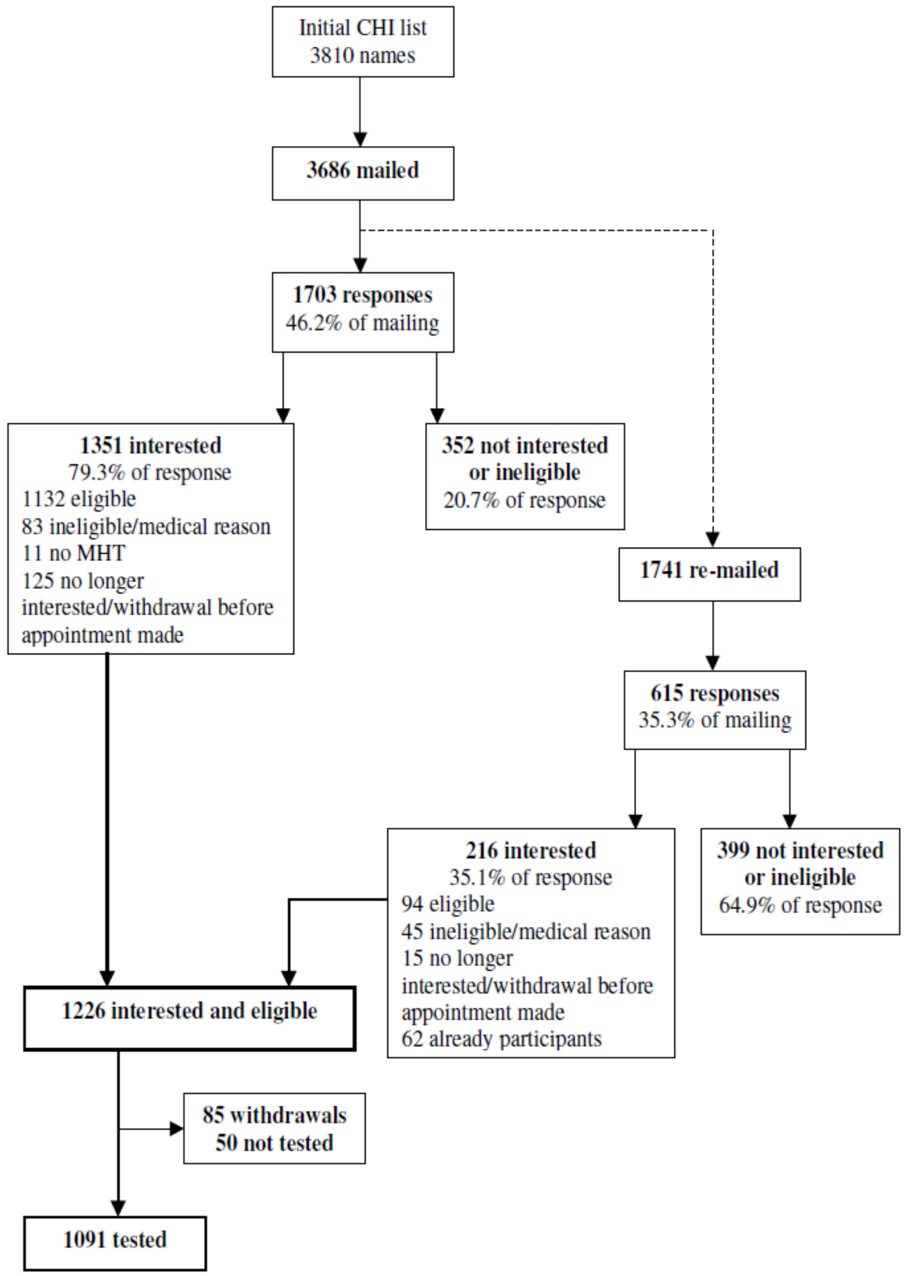


Figure 2.1: Lothian Birth Cohort 1936 Study Timeline. Adapted from Deary et al. (2007).

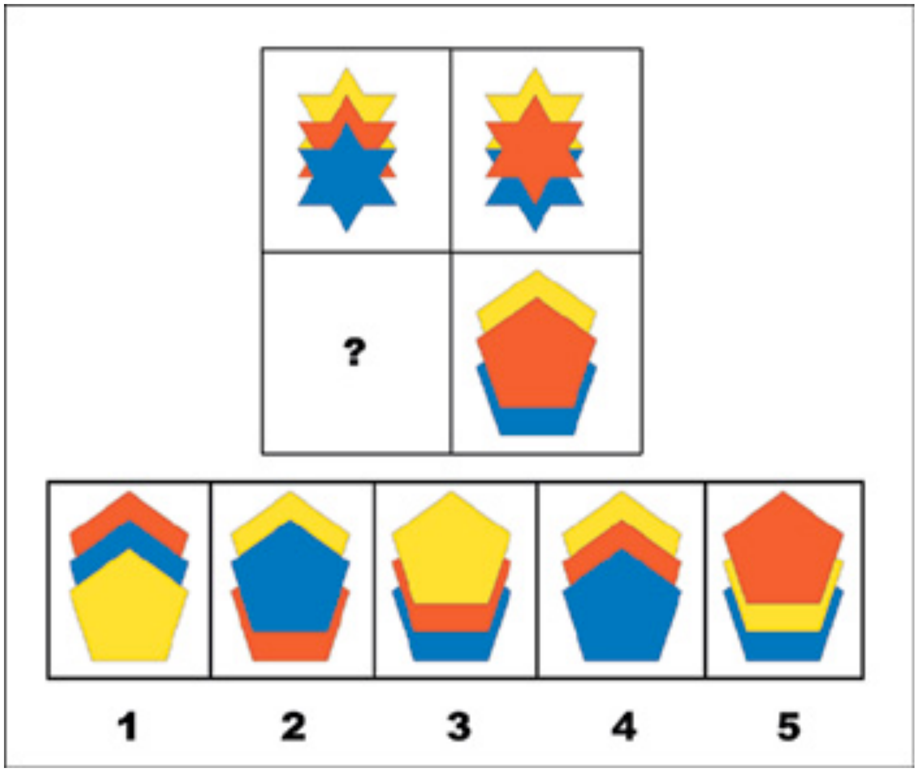


Figure 2.2. An example (taken from the Wechsler Adult Intelligent Scales (WAIS-III^{UK}) of a matrix-reasoning test question in which the participant is asked to select the response that he thinks best fits the missing section.

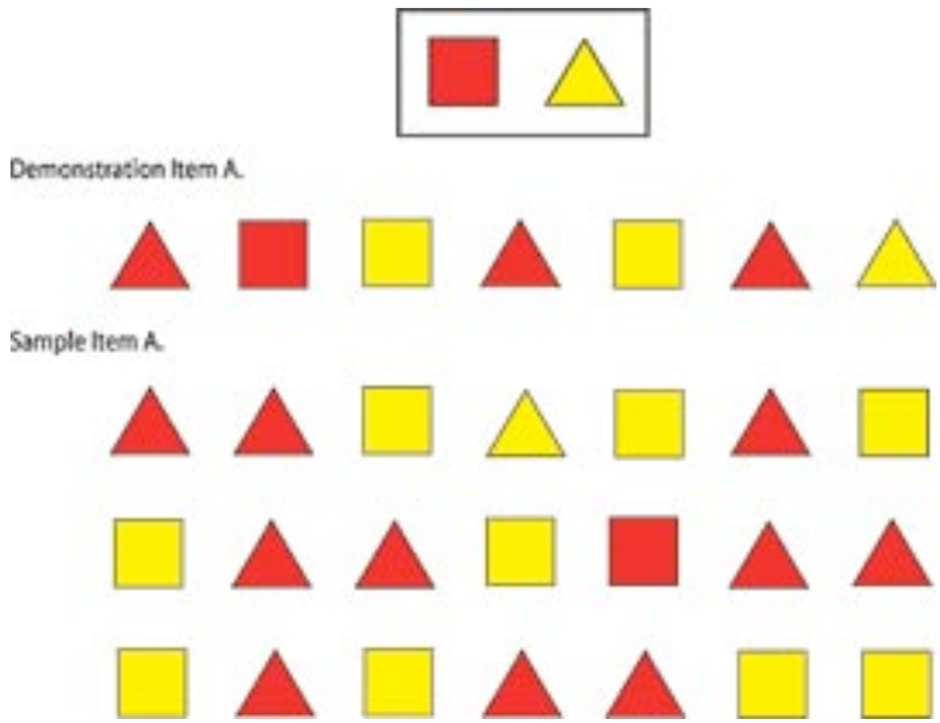


Figure 2.3. An example (taken from the Wechsler Adult Intelligent Scales (WAIS-III^{UK}) of a symbol-search test in which the participant is asked to point out which, if any, of the search group symbols (the two symbols at the top), match the symbols in the target group (those *listed under sample item A*) as quickly as possible.

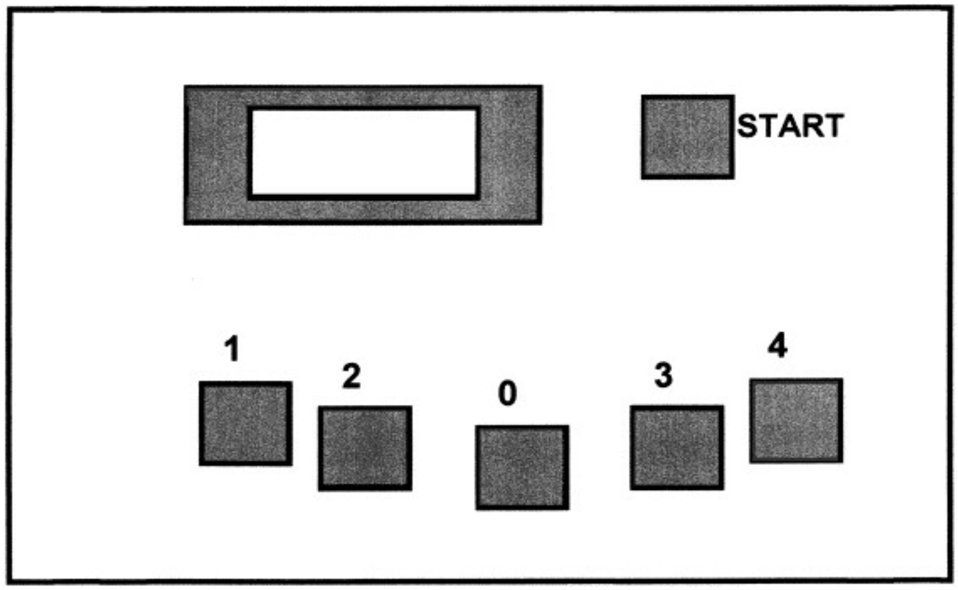


Figure 2.4. The toolbox used to measure reaction time (as illustrated in Deary, Der & Ford, 2011).

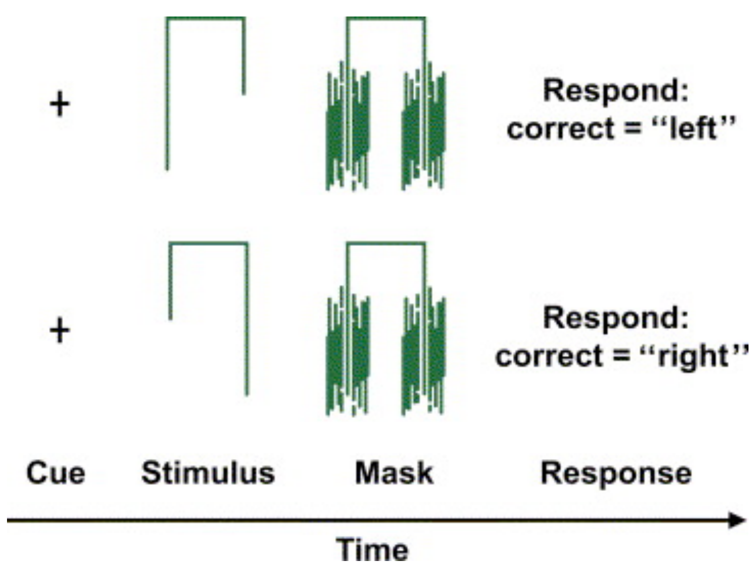


Figure 2.5. An example of the sequence of events in an inspection time trail, in which participants state which line (left or right) they think longer during the stimulus part.

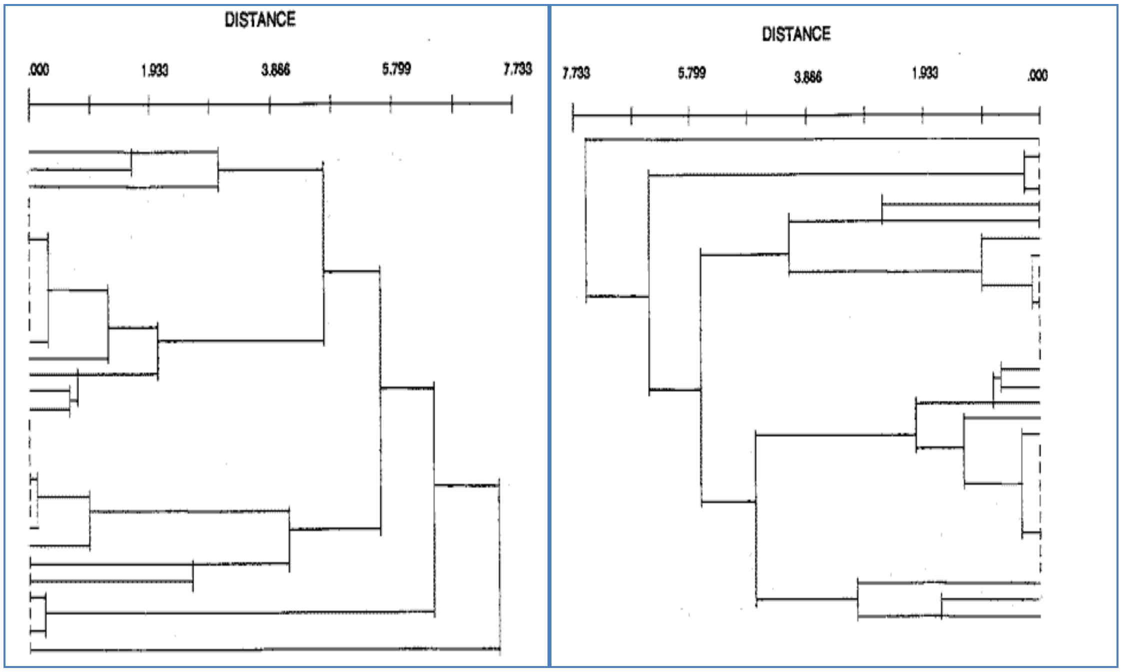


Figure 2.6. Diagram of an agglomerative (left) and a divisive (right) dendrogram using the same data and showing the same results. The y-axis shows the distance at which the clusters form, and the x-axis shows the data points. Each case starts out as its own cluster and eventually all cases become merged into one cluster at the far right of the dendrogram in agglomerative procedures, and all cases start out as one cluster and eventually break down into separate clusters until each case is its own cluster in divisive procedures.

3. The Cognitive Ability Domain

Individuals differ in their cognitive abilities. People who show high ability performance in one cognitive test also tend to show high performance on others, even though the tests' contents vary substantially from one another (Deary, Penke, & Johnson 2010; Deary, 2000). This shared variance across test domains is known as general intelligence, or *g* (Spearman, 1904). *g* is a lifelong relatively stable trait. Individuals tested as children—as assessed using a single test of general intelligence loading highly on *g* rather than a psychometrically derived *g* factor—tend to retain their rank order as late as age 79 (Deary, 2000; Deary, Whalley, Lemmon, Crawford & Starr, 2000). One study that demonstrates this is the Lothian Birth Cohort 1921 study, in which subjects completed the same test (the Moray House Test) at age 11 and at age 79, producing a raw correlation of .63 (Deary et al., 2000). Childhood intelligence contributes at least 50% of the variance to cognitive ability in 80-year old healthy individuals (Deary, Whalley & Starr, 2000). This illustrates that individuals tend to show substantial lifelong stability in cognitive ability differences (Deary, 2000).

Research on cognitive ability in old age can be usefully articulated with reference to the three-stratum model of intelligence differences (Carroll, 1993), which explains variance amongst individuals at three levels and has attracted consensus: specific cognitive tests are found at the bottom (narrow abilities) stratum, higher order latent factors representing the group-based loadings of the cognitive tests are found at the second (broader cognitive domains) level, and the general (*g*) factor is at the highest (general cognitive ability) stratum. A diagram depicting the three-stratum model can be seen in Figure 3.1, which is based on the Wechsler Adult Intelligent Scales-III (Wechsler, 1997) subtest scores; Deary (2001) carried out these analyses on the American standardisation sample of Wechsler Adult Intelligence Scale-III (WAIS-III). Some abilities, better known as crystallized abilities, such as vocabulary, show few or no declines in middle and early old age since they are thought to be affected more by education and other mechanisms of cultural accrual than by age (Malec, Ivnik, Smith, et al., 1992). However, other abilities show age-related declines, the most affected being *g,* with specific effects on memory and speed (Sachie, 2005; Salthouse, 2004, 2010). These are known as ‘fluid’ abilities, and are important in carrying out activities of daily living and living independently (Deary, 2012). Typically, when performance in one domain declines, other abilities also decline (Wilson et al., 2002; Tucker-Drob, 2011).

A number of cognitive ageing theories discuss how age-related declines in *g*, memory and speed may affect each other in old age. Salthouse (1996a, 1996b) was one of the major proponents of the general slowing hypothesis; he maintained that speed predicts cognitive performance especially in memory abilities, thus changes in speed affect memory and, consequently, other cognitive abilities. Opponents to the general slowing hypothesis (e.g. Luo & Craik, 2008) argue that non-speeded tasks, such as free recall, also show age-related decline, and faster processing time does not improve memory-task performance. More recently, Salthouse (2004) proposed an alternative solution where age has effects on *g* as well as specific effects on memory and speed. The reduced inhibitory control hypothesis (Craik & Byrd, 1982; Craik, 2006) proposes that memory decline is due to inhibition decreases with advancing years making it difficult to ignore irrelevant information; however, other factors may be responsible for the decline. The reduced processing resources hypothesis on the other hand, maintains that it becomes more difficult to carry out high-demand tasks because of reduced attentional resources in old age (Hasher & Zacks, 1988). Lastly, the reduced cognitive control hypothesis distinguishes between automatic and consciously controlled memory processing, where automatic processing, such as recognising information remains the same with age, but it becomes increasing difficulty in consciously processing recall information (Hasher & Zacks, 1979). These theories try to explain how age affects cognitive domains and how decline in one may affect decline in another; however, these cognitive abilities also affect broader areas of function outwith these components *per se.*

Cognitive functioning is important for wellbeing in old age (Fillit et al., 2002). It can affect physical health (Deary et al., 2004), quality of life, the abilities to remain active in society, to live independently (Salthouse, 2004), and to deal with consequences of disease (Whalley et al., 2004). Cognitive decline is associated with low quality of life, loss of independence and an increased risk of mortality, making it the most feared aspect of ageing (Morley, 2004).

Lifestyle factors that have been positively associated with better cognitive functioning in old age include regular physical activity, a good well-balanced diet, moderate alcohol intake (especially linked is red wine), not smoking and continued engagement in mentally stimulating activities and social events (Foresight Mental Capital and Wellbeing Project, 2008; Ganguli, Vander, Saxton, Shen et al., 2005; Gow et al., 2007; Nooyens, va Gelder & Verschuren, 2008; Plassman, Williams, Burke, Holsinger et al., 2010; Salthouse, 2009; Seeman et al., 2001). The 'use it or lose it' hypothesis suggests that such continued activity in old age may have positive affects on the structure and/or function of the brain (Fratiglioni, Paillard-Borg & Winblad, 2004; Kramer, Bherer, Colcombe, Dong et al., 2004). A related proposition is the 'cognitive reserve' hypothesis (Richards & Deary, 2005); individuals who have been active throughout their whole lifespan are more likely to remain active and delay onset of age-related cognitive decline owing to the greater reserve capacity they have acquired, therefore high ability in old age may not be due to engaging in stimulating activities per se, but rather due to high stable ability throughout the lifespan. Stable life-long influences such as childhood intelligence and personality traits affect education and job choices, social class, health behaviour and also health that will ultimately affect the maintenance and decline of cognitive ability in old age (Deary, 2012; Deary, Weiss & Batty, 2011).

Research is ready to move from investigating mean changes with age to exploring whether there are differences amongst subgroups of individuals. Thus, a priority in this field, as highlighted by previous work (Kot et al., 1997; Prucho et al., 2010; Smith & Baltes, 1997), is to find out the profiles of these subgroups and in what ways they differ from each other. In this chapter, I attempted to identify and group individuals according to their cognitive ability as determined by the variables that are prominent in the empirical study of cognitive ageing - *g,* Memory and Speed. I first extracted three components from various psychometric and speed-related measures representing *g*, Memory, and Speed (in Section 3.1). I then used two techniques – cluster analysis and latent class analysis (Sections 3.2 and 3.3) – to extract groups of individuals based on their scores on these components, and determine which technique to use for these data. Finally, a number of external variables, relating to demographics, personality, physical and mental wellbeing, health, quality of life, physical fitness, presence of disease, and medication use, were used to characterise the resulting groups (Section 3.4). The aim was to find out patterns of cognitive ability in old age across individuals, and the correlates of high ability. I also aimed to target groups displaying poor functioning, and to identify potentially modifiable factors to avoid preventable poor outcomes.

3.1 Formation of the Cognitive Components

In this section the formation of the cognitive components of *g,* Memory and Speed in the LBC1936 is described.

3.1.1 General cognitive intelligence

Variables constituting general cognitive intelligence (*g*) included six sub-tests from the Wechsler Adult Intelligence Scales (WAIS-III^{UK}, Wechsler, 1997). A description of these variables and all forthcoming ones can be found in Chapter 2

(*Methodology*). Table 3.1 shows the raw mean scores and standard deviations (SDs) of all participants, showing scores for females and males separately.

Pearson's correlation coefficients were computed to test the relation between the WAIS-III^{UK} results' subtests. All subtests correlated significantly with each other at $p < .01$, with no adjustment for multiple testing. This is shown in Table 3.2. The correlation coefficients ranged from .30 between Digit-Symbol Coding and Digit-Span Backwards, to .61 between Digit-Symbol Coding and Symbol Search, with a mean correlation of .43.

Factor analysis[1] using maximum likelihood estimation was conducted on the 6 WAIS-III^{UK} subtests, using an unrotated solution. The Kaiser-Meyer-Olkin measure of sampling adequacy verified the sampling adequacy for the analysis, KMO = .812, and all KMO values for individual items were > .79, which is above the acceptable limit of .5 (Field, 2009). Bartlett's test of sphericity χ^2 (15) = 2109.32, $p < .001$, indicated that correlations between subtests were sufficiently large for factor analysis. An initial analysis was run to obtain eigenvalues for the components in the data. There was only one factor and it had eigenvalues over Kasier's criterion of 1. This explained 43.6% of the variance. Examination of the scree plot showed inflexions that would also justify retaining 1 component. This can be seen in Figure 3.2. All items loaded over .65 on this component. This can be seen in Table 3.3. The subtests that clustered on this component suggested that this represented the general cognitive factor (*g*). The six subtests were analysed for internal consistency reliability estimates using Cronbach's alpha. The internal consistency was .74.

3.1.2 Memory

[1] In this instance only I used factor analysis to create *g;* in all other instances I used principal components analysis to create components. Reasons for this are explained in Chapter 2, Section 2.7.1. I refer to all outcomes as components, even for the *g*-derived factor, to avoid complications.

Psychometric tests that assess memory can typically be classified as verbal and visual, which include immediate and delayed recall and recognition of words and stories. In this study, variables constituting the Memory component included four sub-tests from the Wechsler Memory Scales (WMS-IV^{UK}), namely Logical Memory I and II, and Verbal Paired Associates I and II (WMS-IV^{UK}, Wechsler, 1999). Working memory (WAIS-III^{UK} subtests: *Letter-number sequencing* and *Digit-span backwards*) was assessed as part of *g,* which permitted this section to measure only verbal declarative memory. Table 3.4 shows the raw mean scores and standard deviations of all participants, including scores for males and females separately.

Pearson's correlation coefficients were computed to test the relationship between the WMS-IV^{UK} results' subtests. This is shown in Table 3.5. The correlation matrix shows that all subtests correlated significantly with each other at $p < .01$, with no correction for multiple testing. The correlation coefficients ranged from .42 between Verbal Paired Associates I and Logical memory I, and .85 between Logical Memory I and Logical Memory II, with a mean correlation of .56.

3.1.3 Speed

Processing speed is the ability to process information in a quick way without intentional thinking; it makes use of simple basic motor-movements in response to stimuli. It is a measure of cognitive efficiency. Variables constituting the Speed component in this study included the means in milliseconds (ms) for simple and four-choice reaction time (SRT and CTR), and total number of correct responses for visual inspection time (IT) tasks. Table 3.7 shows the raw mean scores and standard deviations (SDs) of all subjects together and separately for males and females.

Pearson's correlation coefficients were computed to test the relations among the chronometric speed tests. The IT variable was reversed to match the format of SRT and CRT, and have all variables in the same direction. All subtests correlated significantly at $p < .01$, with no adjustment for multiple testing. The correlations ranged from .18 between inspection time and simple reaction time to .48 between simple reaction time and choice reaction time, with a mean score of .33. This is shown in Table 3.8.

Principal components analysis was conducted on the three chronometric speed measures, using an unrotated solution. The Kaiser-Meyer-Olkin measures of sampling adequacy verified the sampling adequacy for the analysis, KMO = .561, and all KMO values for individual items were > .540, which is above the limit of .5 (Field, 2009). Bartlett's test of sphericity χ^2 (3) = 402.18, $p < .0001$, indicated that the correlations between the subtests were sufficiently large for principal components analysis. An initial analysis was run to obtain eigenvalues for the components in the data. There was only one component and it had one eigenvalue over Kasier's criterion of 1. This explained 56.1% of the total variance. Examination of the scree plot showed inflexions that would also justify retaining 1 component. This can be seen in Figure 3.4. All items loaded over .64. This can be seen in Table 3.9. The subtests that clustered on this component suggested that this represented speed. The three tests were analysed for internal consistency estimates using Cronbach's alpha for reliability analysis. The internal consistency was .55.

3.1.4 The Cognitive Ability components

The three cognitive components: *g*, Memory and Speed derived from the principal components analyses were tested for outliers using boxplots. Each of the components showed outliers; however, these were winsorized, thus any score which fell above or below three standard deviations (SDs) was adjusted to either -3 or +3 SDs, depending on whether the outlier was below or above the mean respectively. This process avoided deleting cases that may have highlighted trends of low or high scoring subgroups, but simultaneously avoided extreme outliers that could have influenced the results. Box plots of the three components with winsorized scores can be seen in Figure 3.5.

The Speed component was reversed (by multiplying it by -1) so that a higher response equated to faster reaction time. Pearson's correlations coefficients were computed for the three cognitive components. All components correlated significantly at $p < .01$, with no adjustment for multiple testing. The correlations ranged from .191 between Memory and Speed to .446 between *g* and Memory. The remaining correlation between *g* and Speed was .261. The correlation table can be seen in Table 3.10.

3.2 Formation of groups using cluster analysis

In the previous section I defined three broad areas of cognitive ability representing *g*, Memory and Speed. To investigate whether these variables distinguished subgroups of individuals within the LBC1936 exist with regard to cognitive ability at age 70 I first applied cluster analysis using these components.

Participants (n = 1091) were randomly allocated into two mutually exclusive samples (Sample 1, n = 525, and Sample 2, n = 566) with the aim of creating two datasets that could be viewed as replication samples, as has been previously suggested (Aldenderfer and Blashfield, 1984). Cases with missing data were excluded for this analysis (Sample 1, n = 35, and Sample 2, n = 50). This resulted in 490 participants in Sample 1 and 516 participants in Sample 2.

A hierarchal agglomerative procedure was first run to establish the number of clusters and to profile the cluster centres. I chose Ward's method to cluster the cases in order to minimise within-cluster variance and to avoid problems with forming many tiny clusters as in single-linkage (Ward, 1963), and applied Euclidean squared as the distance measurement to assess similarity amongst cases; this method has been found to be efficient and complimentary to Ward's method (Hair, Anderson, Tatham & Black, 1998). These were independently applied in each dataset. The dendrograms from Ward's hierarchal procedure suggested 4 or 6 clusters in both samples. These can be seen in Figure 3.6.

Using the initial centroids obtained from the hierarchal analysis, I ran a K-means iterative partitioning to confirm the cluster solutions were actually distinct. As required by K-means analysis, the number of clusters had to be pre-specified for it to assign cases into clusters. The final centroid values and the cluster sizes of Samples 1 and 2 with both 4- and 6-cluster solutions can be seen in Tables 3.11 and 3.12. Here the mean scores of each of the separate clusters can be seen along with the total numbers of individuals in each group. These portrayed high functioning, average functioning, and low functioning groups. The tables also show ANOVA results of between- cluster differences in means - both the 4- and 6-cluster solutions in Samples 1 and 2 showed significant differences among cluster-means. This shows that cognitive function scores in both the 4- and 6-cluster groups were significantly different from one another.

3.2.1 Validation and profiling of the 4- and 6-cluster solutions

Hair et al. (1998), suggest two steps in the final stage of exploratory cluster analysis. Firstly, to assess the stability of the clusters by running a second K-means analysis allowing the procedure to run with random initial seed points. Usually, the starting point of the cluster seeds depends on how the data are ordered. By randomising initial seed points the data are reordered; similar results will provide further validation of the cluster solutions (Hair et al., 1998). The results in Tables 3.13 and Table 3.14 show consistency for both the 4- and 6-cluster solutions; the cluster sizes are identical for each solution (i.e. initial and random seed-points produced the same cluster-centre means in both solutions). This shows that the results were stable.

Secondly, Hair et al. (1998) suggest assessing the predictive validity of both solutions. I conducted an analysis of variance on the 4- and 6-cluster solutions using two external variables, which are theoretically related to the area of study, age-70 IQ variables with *g*, Memory and Speed, if significant differences are found on these variables, the cluster-solutions can be assumed to have predictive validity. Tables 3.15 and 3.16 show that significant differences on these variables were found in both the 4- and 6-cluster solutions.

Since both cluster-solutions seemed valid I described both - Tables 3.17 and 3.18 show the profiles of 4- and 6-cluster solutions, and Figures 3.7 and 3.8 show a graphical representation of these. In both samples of the 4-cluster solution there was a High-Ability and a Low-Ability group. Of the two remaining groups, one group performed relatively high on Memory and low on *g* and Speed, and another group performed relatively low on Memory but better on *g* and Speed, in both samples. In both samples the High Ability group contained most of the cases (34% and 27% in samples 1 and 2), whilst the Low Ability group contained the least (16% and 19% in samples 1 and 2). The 6-cluster solution in both samples showed a similar pattern of scores to the 4-cluster solution in four of the clusters (Clusters 1, 3, 4 and 6 in both samples). The other two clusters, 4 and 5, represented groups that either scored averagely or below average across all variables. However, the 4-cluster solution was more consistent between both samples; patterns and cluster-sizes were better replicated between samples in the 4-cluster solution than those in the 6-cluster solution. Furthermore, in the 6-cluster solution, there were clusters as small as 39 cases and as big as 102. This may have indicated that the 6-cluster solution had more homogenous clusters in that it consisted of groups that scored in a similar pattern across variables but at different level-scores, e.g. clusters 4 and 5 in Sample 1 showed a similar pattern - both scored higher on Memory and lower on *g* and Speed, however, scores in cluster 4 were higher across all variables than in cluster 5 despite that both clusters had similar patterns of scores across the variables. Authors (e.g. Hair et al., 1998) note the importance of avoiding widely varying cluster sizes since they may not represent a valid structure component or may just be unrepresentative of the population. Due to these reasons results seemed to show that groups in the 4-cluster solution were more evenly distributed between samples and more parsimonious; it seemed like a better solution.

3.2.2 Summary of results 1

Cluster analysis was used to explore the Cognitive Ability data. The whole sample was randomly divided in two to find out whether the two subsamples replicated each other well. The dendrogram from hierarchal agglomerative analysis seemed to suggest four or six clusters in both sub-samples. Replication, non-hierarchal clustering and ANOVA on external variables, were used as validation techniques. Results supported the external validity for both the 4- and 6-cluster solutions. After profiling the cluster solutions, the 4-cluster solution had similar cluster-sizes across both samples, as opposed to the 6-cluster solution, which had inconsistent cluster-sizes. It was also a more parsimonious solution.

Cluster analysis here was only used as an exploratory technique as suggested by various authors (e.g. Aldenderfer & Blashfield, 1984). Strong conclusions could not be reached for various reasons: other researchers might have interpreted the dendrogram from the hierarchal analysis differently, and a different number of clusters to classify the data might have been pursued. Since neither hierarchal procedures nor K-means analysis provide any probabilistic models of membership or fit-criteria, there was not much information to work on, and choosing amongst solutions was more a matter of intuition than of scientific objectivity.

Another attempt at classifying the data using latent class analysis was also used to find out if solutions from this technique indicated similar results as generated from cluster analysis. This is discussed next.

3.3 Formation of groups using latent class analysis

In Section 3.1 I derived three broad areas of cognitive function representing *g*, Memory, and Speed from factor analysis and principal components analysis. These were standardized and analysed as z-scores (mean = 0, standard deviation = 1) and used as such throughout the whole study to avoid complications comparing results. The cognitive components had already been checked for normality and outliers in a previous section (Section 3.1.4).

In Section 3.2 I applied cluster analysis (CA) to the cognitive components as an exploratory technique. In this third section, I used a second approach, latent class analysis (LCA), to group together participants according to their scores. The aim was to compare this technique and its results with cluster analysis. To identify cognitive profiles in the LBC1936, I ran a latent class analysis using participants' component scores on *g*, Memory, and Speed were subjected to LCA.

I started by running models with two-, three-, four-, five- and six-group solutions on MPlus (Muthen & Muthen, 2004). Results were then compared using the Akaike information criterion (AIC), the Bayesian information criterion (BIC), and adjusted BIC (Table 3.19). Although typically lower figures depict a better model, here the fit kept improving with every added group, which probably was an indication that there were not actual classes in the data as is common with continuous measures. Despite this, there was a greater improvement in fit statistics from 2 and 3 groups (a difference of 111.64) to 3 and 4 groups (a difference of 27.49) than from 3 and 4 groups to 4 and 5 groups (difference of 3.82) suggesting that the fit improved greatly between 3 and 4 groups. Furthermore, the 4-group solution had the best entropy (ENT) (0.77); however, this group also had a subgroup containing only 1.1% of the whole sample. This was also the case for the 5-group solution (ENT = 0.72), which had two subgroups containing 1.1% and 2.4% of the population. The three-group solution (.73) on the other hand, seemed to combine the lowest scoring groups (2 in the 4- and 3 in the 5- class solutions) into one group making up 3.5% of the sample. Although this figure was still low (lower than the cut-off 5% I had initially planned on in *Methodology*), it seemed to have grouped individuals with the lowest scores on these measures into one group (as opposed to 2 or 3 groups in the 4 or 5 group solution), hence more parsimony. Unlike the 2-group solution, the 3-group solution also avoided grouping together a few low scoring individuals with a bigger group, which would have potentially missed out on the qualities of this set of individuals. Results in the 3-group solution also showed that although the low and average scoring groups did not show significant differences on Memory, there were considerable differences on *g* and Speed, a result that was not captured in the 2-group solution. For these reason I opted for the 3-group solution. Participants were assigned to the group to which they had the highest probability of belonging according to their responses on *g,* Memory, and Speed as depicted by LCA. For most likely group-membership, the probabilities ranged from .81 to .90, indicating a clear group membership for the majority of the participants. Table 3.20 illustrates group membership probabilities as they were predicted by LCA. Previous studies (e.g., Smith & Baltes, 1997; Gerstorf, et al., 2006) that have looked at profiles of functioning across individuals have typically focused on cluster analysis (CA) to characterise group patterns. In this study, I made use of both CA and LCA.

Results from these techniques indicated 4- (in CA) and 3- (in LCA) group solutions as appropriate. These techniques divided the sample into quartiles and tertiles without suggesting any qualitative differences amongst the groups. If a 4-group solution were pursued in the LCA, patterns of scores across variables would have resembled the one derived from CA i.e. an additional lower scoring group. An illustration of a 4-group solution derived by LCA is in Figure 3.10 to help demonstrate the similarities of patterns of results of the 4-group solutions in both CA and LCA. However, given the group size of the 4th group (i.e. < 1%) in the LCA, the 3-group solution seemed a suitable compromise.

3.3.1 Profiles of the latent groups

The 3-group solution was selected for further analysis. Group 1 was the biggest group (n=794, 69%); it scored highly on all measures of Cognitive Ability, and was named the High Cognition group. Groups 2 and 3 did not differ significantly on Memory scores; only *g* and Speed distinguished between those groups. Group 2 consisted of 303 participants (28%) and showed average scores on *g* and Speed, and was thus named Average Cognition. The remaining group, Low Cognition consisted of 39 participants (4%) and had poor scores on *g* and Speed. Table 3.21 shows the means and standard deviations of each of the groups on each of the cognitive components. Figure 3.9 illustrates this.

LCA results seemed to suggest that cognitive ability across domains was uni-dimensional (i.e. ranging from low to high wellbeing). There were no interactions on the components between groups – a majority scored consistently high across all components of Cognitive Ability, whereas individuals in the Low Cognition showed the same pattern of low scores across all components, and although the Average Cognition group had a higher score on Speed than on *g* or Memory all scores were still within average of the other two groups. Furthermore, the similar means from both Average and Low Cognition groups on Memory suggested that this variable was not giving much information for these two groups; however, it was still useful since it distinguished them from the High Cognition group. *g* and Speed, on the other hand, significantly distinguished amongst all three groups. This pattern of scores may indicate that cognitive abilities in old age reflect one another; hence if functioning in one domain declines functioning in another may also decline. Although this is a cross-sectional study, its results indicate findings from current research on cognitive ageing that the relationship amongst cognitive abilities is linear and low ability on one component often reflects low ability on other components (Tucker-Drob, 2011; Salthouse, 2004), hence a pattern of scores with no indication of either of the groups showing a high pattern of scores on one component and low on another. Despite this, it was still useful to "cut" the continuum into groups to find out the characteristics that differentiated amongst High, Average, and Low cognition groups.

3.3.2 Summary of results 2

Results from latent class analysis (LCA) in this study indicated that the existing differences in cognitive ability amongst 70-year-olds are not qualitative and individuals in this regard are unlikely to belong to mutually exclusive groups. Specifically results indicated a dimensional pattern of high, average and low-scoring individuals on measures of cognitive ability with no distinctive groups showing uneven patterns across components. Despite this, the use of LCA has helped in portraying cognitive ability in old age in healthy adults.

CA and LCA indicated similar possibilities of group-solutions; the 4-group solution derived from both techniques produced similar patterns of results. However, true classifications in my dataset were unknown, and I found LCA to offer more advantages than CA. Firstly, LCA is a posterior probability-based classification allowing the cases to be classified into groups using posterior membership probabilities based on the concept of maximum likelihood estimation methods. This means that each case is assigned a group membership probability ranging from 0 to 1 with values closer to 1 indicating a higher degree of certainty in membership classification, and values closer to

0 indicating lower certainty. In cluster analysis, K-means uses an *ad-hoc* approach and does not assign probabilities to group membership thus giving the cases a weight of either a 0 or a 1, which may bias the cluster-means. Secondly, LCA provided me with a range of model fit indices (BIC, AIC, adj. BIC, and ENT) to help me determine the number of groups. K-means clustering offers no such assistance. Finally, LCA has become an increasingly promising technique, which has been shown to outperform more *ad-hoc* traditional methods such as K-means (Lanza, Flahery & Collins, 2003; Magidson & Vermunt, 2002; Vermunt & Magidson, 2002). I thought it best to proceed with LCA since it provides more statistical information for a better-informed decision. For these reasons I only made use of LCA procedures to group individuals based on their scores in the forthcoming studies on psychosocial wellbeing and physical function at age 70.

In the next section I use several external variables relating to demographics, personality, physical and mental wellbeing, health, quality of life, physical fitness, presence of disease, and medication use to characterise the three groups I derived from LCA.

3.4 Descriptors and Predictors of Cognitive Ability at age 70

In the previous section I applied LCA to the LBC1936, with the aim of generating groups of 70-year old individuals according to their cognitive abilities as measured by *g,* Memory, and Speed. Results supported a 3-group solution consisting of high-, average-, and low- ability individuals. The majority of the cases belonged to the High Cognition group (69%); however, a substantial number also belonged to the Average Cognition group (28%). Only a small minority (4%) showed low ability. This pattern of scores (low, average, high) suggested that I was dealing with a continuum of scores rather than a dataset with qualitatively different subgroups.

The aim of this section was to explore how the three cognitive ability groups differed on external variables relating to demographic, personality, health, physical status, presence of disease, physical and mental wellbeing, quality of life measures, and medication-use and diagnosed medical conditions. A thorough description of all the variables examined in this chapter can be found in Chapter 2, entitled *Methodology*. In all instances, analyses of variance (ANOVA) were first used to determine whether significant differences were present amongst the classes on any of the variables. Post-hoc analysis for the significant findings from ANOVA using Tukey's Honestly Significant Difference (HSD) test comparisons was also administered to find out which groups differed significantly from each other. This was followed by multinomial logistic regression to predict group membership for each of the variables considered[2]. The multinomial regression also allowed analysis for the strength and direction group membership may have on external variables. The High Cognition group was used as the baseline group in all multinomial logistic regression analyses run in this chapter. The logistic regression *p*-values were also adjusted for multiple testing amongst variables using the Bonferroni correction in all instances. The logistic regressions were included as an extension of the mean-comparison tests. The external variables were chosen to provide descriptive data of the three groups and to explore how they distinguished amongst them. The main aim of this was to summarise how differences in cognition in old age may relate to other outcome variables. A Venn diagram illustrating the results can be seen in Figure 3.11.

3.4.1 Demographic measures and prior cognitive ability

The first set of variables, demographic measures and two variables measuring prior cognitive ability, used to explore differences amongst the groups were sex, number of years in full time education, the National Adult Reading Test (NART) scores, marital status, living status (whether alone or not), social class and age-11 IQ. Tables 3.22 and 3.23 show the raw means, standard deviations, and mean differences in these variables for each of the three classes. Variables that significantly distinguished amongst the

[2] More detail on why I used both ANOVAs and MLRs on external variables is given in Chapter 2, Section 2.7.2. This applies for the rest of the chapters.

groups were then followed up with post-hoc analysis, using Tukey's HSD. Table 3.24 shows the results.

Significant differences were found for Age-11 IQ, NART, total number of years in education, sex, marital status, living status, and social class. The High Cognition group scored significantly higher on age 11 IQ (effects sizes ranging from 1.09 to 1.64) and the NART (effect sizes ranging from 1.12 to 1.60). It also had more years of education (effect sizes ranging from 0.70 to 0.90). A higher proportion of individuals in this group also belonged to the professional social class and who were still married (73.2%), as opposed to being widowed, separated or divorced. The Low Cognition group had a significantly higher number of males (79%) than the rest of the groups (48.2% for High Cognition and 51.5% for Average Cognition). It also contained the highest number of widowers (30.8%).

Results from the multinomial logistic regressions showed that the odds for males rather than females to belong to the Low Cognition group were 3.11 (CI = 1.48 – 6.53). For every added year in education the likelihood of belonging to the Average Cognition group was .83, and for every unit increase in age- 11 IQ the odds of belonging to the Average or Low Cognition groups rather than the High Cognition group were .94 and .92. The analogous odds ratios for each point of the NART were 0.87 and 0.84 for the Average and Low Cognition groups. Furthermore, individuals in the Low Cognition were less likely to be married (OR = 1.45). The odds of belonging to the Low Cognition group rather than the High Cognition group for every decrease in social class were 2.55. Results can be seen in Table 3.25.

3.4.2 Personality measures

Similar procedures were used to compare groups on measures of personality. Measures from the NEO- Personality Inventory were used to measure personality. Results depicting the raw scores, standard deviations, and differences amongst the groups can be seen in Table 3.26. Significant differences, although not strong, were found in Neuroticism scores (effects sizes ranging from 0.10 to 0.32), Openness (effect sizes ranging from 0.23 to 0.78) and Agreeableness (effect sizes ranging from 0.03 to 0.15). Post-hoc results showed that the High Cognition group had the highest scores on Openness and Agreeableness, and the lowest scores on Neuroticism, whereas the Low Cognition group had the opposite trend; i.e., the lowest scores on Openness and Agreeableness and the highest scores on Neuroticism. Tables 3.26 and 3.27 show the results.

Results from the multinomial logistic regression showed that for every point score increase in Neuroticism the odds of belonging to the Average wellbeing group rather than the High Wellbeing group were 1.04. For every score increase in Openness it was less likely to belong to the Average and Low Cognition groups rather than the High Cognition group (ORs =.90 and .89, respectively). Lastly, for every score increase in Agreeableness it was less likely to belong to the Low Cognition group than the High Cognition group (OR = .90). Table 3.28 shows the results.

3.4.3 Physical and Mental Wellbeing

Variables reflecting physical and mental wellbeing, including scores from the Hospital Anxiety and Depression Scales (HADS), activities of daily living (ADLs), and level of physical activity, were also used to explore differences amongst the groups. These were included in the ANOVAs as dependent variables, and the groups as independent variables. Table 3.29 shows the means, standard deviations, and ANOVA results. No significant mean differences in any of the variables were found amongst either of the groups. Table 3.30 also shows that no significant results were found in the multinomial regression analyses.

3.4.4 Health

Variables relating to health, including body mass index (BMI), units of alcohol consumed per week, smoking status, and the presence/absence of the APOE e4 allele were submitted in ANOVA as dependent variables and the three groups as the independent variable. Tables 3.31 and 3.32 show the means, standard deviations, and *p* values of these variables for each of the groups. The only significant differences (Table 3.33) were found for units of alcohol per week between the High and Average Cognition groups (d = 0.20) with higher alcohol intake in the High Cognition group. BMI also predicted group membership; the odds of belonging to the Average or Low Cognition groups as opposed to the High Cognition group were 1.03 and 1.07, respectively. Table 3.34 shows these results.

3.4.5 Quality of life

I also used variables from the World Health Organisation Quality of Life scales (WHO-QOL) including physical, psychological, social, and environmental wellbeing to explore differences amongst the groups. No significant mean differences were found amongst the groups on any of the variables (Table 3.35). Results from the multinomial logistic regression showed that none of the variables predicted group membership. Table 3.36 shows the results.

3.4.6 Physical fitness measures

Physical measures, including forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), 6-metre walk-time, and grip strength were submitted into ANOVA as dependent variables and the groups as the independent variable. No significant differences were found. Table 3.37 shows the results. Results from the multinomial logistic regression also showed that none of the variables predicted group membership. This can be seen in Table 3.38.

3.4.7 Disease status

Measures relating to presence or absence of high blood pressure, diabetes, cardiovascular disease, circulation problems and stroke were also used to explore differences amongst the groups. Significant differences were present between the High and Average Cognition groups whereby a higher percentage of individuals in the Average Cognition group (34.1%) had cardiovascular disease. Tables 3.39 and 3.40 show the results. This variable also predicted group membership in the multinomial logistic regression. The odds of belonging to the Average Cognition group as opposed to the High Cognition group for presence of history of cardiovascular disease were 1.62. Individuals in the Average and Low Cognition groups also had higher odds of having suffered stroke (1.65 and 3.02 respectively) as opposed to the High Cognition group. Table 3.41 shows the results.

3.4.8 Medication and medical conditions

I also looked at number of diagnosed medical conditions and total number of drugs taken – these were entered into ANOVA as dependent variables. The groups were entered as the independent variables. Table 3.42 shows the means, standard deviations and ANOVA results. Significant differences ($d = 0.20$) were present between the High and Average groups (Table 3.43) in number of medications taken, with the Average Cognition group being on more medications than the High Cognition group. This variable also predicted Low and Average Cognition membership in the multinomial logistic regression where for every drug the odds ratios of belonging to these groups, as opposed to the High Cognition group, were 1.10 and 1.56. Table 3.44 shows the results.

3.4.9 Summary of results 3

Descriptive analyses were carried out on each of the three groups, specifically the High, Average and Low Cognition groups, using a wide range of variables relating to demographic, personality, health, physical status, presence of disease, physical and mental wellbeing, quality of life measures, and medication use and medical conditions. The High Cognition group had the most favourable characteristics on these variables. This group had a significantly higher mean age-11 IQ, higher mean scores on the NART, on average more years spent in formal education, on average more individuals in this group belonged to a higher social class, had lower mean scores on measures of Neuroticism, and higher mean scores on measures of Agreeableness and Openness. The opposite trend was present in the Low Cognition group i.e. it had significantly lower mean age-11 IQ, lower mean scores on the NART, lower mean number of years spent in formal education, a lower mean social class, higher mean scores on Neuroticism, and lower mean scores on Agreeableness and Openness, a higher mean number of medications and more medical illness (participants in this group were more likely to have suffered stroke). The main distinguishing feature of the Average Cognition group was the presence of a higher percentage of people with a history of CVD and stroke than the rest of the groups.

The results from this study also indicated the presence of a strong dimension in this sample's cognitive ability. The majority belonged to the High Cognition group, which scored relatively well across cognitive and external variables, and a minority scored poorly across cognitive and external variables. There was also an average-scoring group whose scores fell in between the High Cognition and Low Cognition groups. This implied a one-dimensional result of cognitive ability in this age group, with smaller groups scoring either averagely or in minor cases, poorly. This supported previous research (e.g. Smith & Baltes, 1997) where individuals who tend to score highly on one wellbeing-variable, also tend to score highly on other variables, and vice-versa. Because the study was cross-sectional, it was not possible to interpret the direction of effects i.e. whether these variables (e.g. Openness, high social class) were causes or consequences of high cognitive ability in old age. Furthermore, these trends of cognitive function in old age may have been present when the individuals were children and carried on into their adulthood and older years; hence these are by no means reflections of cognitive function in just old age, but possibly a life-long pattern of cognitive ability.

3.5 Final conclusions

The primary aim of this study was to identify patterns of Cognitive Ability among 70-year old individuals by entering measures of *g*, Speed, and Memory into latent class analysis. External variables representing measures of demographics and prior cognitive ability, personality, health, physical and mental wellbeing, and quality of life were used to describe and explore differences amongst the generated groups. Results showed that individuals at the higher end of the cognitive spectrum were more likely to display more favourable qualities in many other areas of life than the rest of the sample. Absence of significant differences for some variables among some of the classes was also present (e.g. Memory did not show any significant differences between the Average and Low Cognition groups). Results also failed to confirm the presence of distinct classes of cognitive function amongst the groups. It was thus concluded that cognitive function in old age is best seen as a continuum amongst individuals ranging from high ability to average and low ability individuals.

Several authors (Gerstorf, Smith, & Baltes, 2006; Smith & Baltes, 1997; Garfein & Herzog, 1995) in this field have classified individuals into successful and less successful groups to generate class profiles in the older population; most of these studies have looked at a wide variety of bio-psychosocial domains rather than just one. In this study, cognition was the only domain used to explore differences amongst individuals, hence narrowing down the wide concept of successful ageing to just cognitive functioning in individuals at age 70. Since the cognitive variables have a known association amongst themselves, distinct profiles of ability amongst groups of individuals were not expected. However, results reflected current research (e.g. Depp, Vahia & Jeste, 2010; Friedman, Kern & Reynolds, 2010; Gow et al., 2007) into ageing on the associates of high cognitive ability, namely more years in education, a better social class, positive personality traits and better health. The results form this study showed that cognitive ability, even in old age, is associated with most areas of life. In the next chapter I will explore if this is also true of psychosocial wellbeing.

Table 3.1
Means of the Wechsler Adult Intelligence Scales (WAIS-III^{UK}) subtests for total participants, males and females (SDs in parentheses).

WAIS subtests	Total participants n = 1072	Males n = 536	Females n = 536
Symbol search	24.71 (6.39)	24.68 (6.60)	24.73 (4.08)
Digit symbol coding	56.60 (12.93)	54.66 (13.86)	58.55 (12.38)
Matrix reasoning	13.49 (5.13)	14.05 (5.16)	12.94 (5.05)
Digit span backwards	7.73 (2.26)	7.78 (2.31)	7.69 (2.21)
Letter number sequencing	10.92 (3.16)	10.99 (3.24)	10.86 (3.07)
Block design	33.79 (10.32)	35.56 (10.55)	32.01 (9.78)

Table 3.2
Correlation coefficients amongst the Wechsler Adult Intelligence Subscales (WAIS-III^{UK}) results' subtests for General Cognitive Ability.

	1	2	3	4	5	6
1. Matrix Reasoning	-					
2. Letter-Number Sequencing	.442**	-				
3. Digit-Span Backwards	.401**	.540**	-			
4. Block Design	.571**	.402**	.337**	-		
5. Symbol Search	.450**	.454**	.344**	.483**	-	
6. Digit Symbol Coding	.366**	.413**	.302**	.394**	.618**	-

** Correlation is significant at $p < .01$ (Pearson's r, 2 tailed), no adjustment for multiple testing.

Table 3.3

Component loadings for the first unrotated principal component of six WAIS-III^{UK} subtests reflecting General Cognitive Ability.

Variables	Loadings
Symbol Search	.73
Letter-Number Sequencing	.67
Matrix Reasoning	.67
Block Design	.67
Digit Symbol Coding	.65
Digit Span Backwards	.53

Table 3.4

Means of the Wechsler Memory Scales (WMS-IV^{UK}) subtests for total subjects, males and females (SDs in parentheses).

WMS subtests	Total subjects N = 1091	Males (M) N = 548	Females (F) N = 543
Logical Memory I	43.95 (10.67)	42.93 (11.25)	44.99 (9.95)
Logical Memory II	27.20 (8.23)	26.23 (8.60)	28.18 (7.72)
VPA I	19.64 (8.06)	18.42 (7.97)	20.86 (7.98)
VPA II	5.95 (2.32)	5.68 (2.40)	6.21 (2.21)

Note. VPA = Verbal Paired Associates.

Table 3.5
Correlation coefficients for the Wechsler Memory Scales (WMS-IV^{UK}) results' subtests.

		1	2	3	4
1.	Logical memory I	-			
2.	Logical memory II	.854**	-		
3.	VPA I	.423**	.460**	-	
4.	VPA II	.384**	.430**	.836**	-

Note. VPA = Verbal Paired Associates. ** Correlation was significant at $p < .01$ (Pearson's r, 2 tailed), with no adjustment for multiple testing.

Table 3.6
Component loadings for the first unrotated principal component of the four Wechsler Memory Scales WMS- III^{UK} subtests used in this study.

Variables	Loadings
Logical Memory I	.90
Logical Memory II	.94
Verbal Paired Associates I	.52
Verbal Paired Associates II	.48

Table 3.7

Raw means for speed measures for total subjects, males and females (SDs in parentheses).

Chronometric speed measures	Total subjects n = 1091	Males n = 548	Females n = 536
SRT (ms)	.28 (.06)	.28 (.06)	.28 (.05)
CRT (ms)	.64 (.86)	.64 (.09)	.64 (.08)
IT (total number of correct responses)	112.1 (11.00)	113.9 (10.63)	110.4 (11.09)

Note. SRT = Simple Reaction Time. CRT = Choice Reaction Time. IT = Inspection Time. ms = milliseconds.

Table 3.8

Correlation coefficients for the variables representing speed.

	1	2	3
SRT	-		
CRT	.482**	-	
IT	.176**	.359**	-

Note. SRT = Simple Reaction Time. CRT = Choice Reaction Time. IT = Inspection Time. ** Correlation was significant at $p < .01$ (Pearson's r, 2 tailed), without adjustment for multiple testing.

Table 3.9

Component loadings for principal components analysis for the first unrotated principal component.

Variables	Loadings
CRT	.89
SRT	.75
IT	.64

Note. CRT = Choice Reaction Time. SRT = Simple Reaction Time. IT = Inspection Time.

Table 3.10.

Correlation coefficients between the cognitive components.

		1	2	3
1.	*g*	-		
2.	Memory	.446**	-	
3.	Speed	.261**	.191**	-

Note. g = General Cognitive Intelligence. ** Correlation significant at $p < .01$ (Pearson's r, 2-tailed), with no adjustment for multiple testing.

Table 3.11

Four-cluster solution centre means of the k-means non-iterative partitioning with initial seed points from the hierarchal cluster analysis results for Sample 1 and 2 with significance values.

	Final cluster centres							
Cluster	Memory		*g*		Speed		n	
	S1	S2	S1	S2	S1	S2	S1	S2
1	.49	.52	-.19	-.12	-.62	-.36	109	157
2	-1.01	-1.03	-1.09	-1.09	-1.10	-1.26	76	100
3	-.59	.66	.04	.92	.57	.74	139	141
4	.81	-.85	.78	-.05	.61	.62	166	118
F	278.6	235.1	174.8	222.4	221.5	291.6		
df	3	3	3	3	3	3		
p	.001	.001	.001	.001	.001	.001		

Note. g = General Cognitive Ability. S1 = Sample 1. S2 = Sample 2. No adjustments for multiple testing were made. *p* value as derived from ANOVA.

Table 3.12

Six -cluster solution centre means of the k-means non-iterative partitioning with initial seed points from the hierarchal cluster analysis results for Samples 1 and 2 with significance values.

	Final cluster centre means							
Cluster	Memory		*g*		Speed		n	
	S1	S2	S1	S2	S1	S2	S1	S2
1	-.66	.52	.48	-.25	.62	-.3	87	134
2	-.96	-.89	-1.22	-.05	-1.82	.76	38	94
3	.49	.98	-.18	.74	-.61	.88	102	98
4	-.86	-.63	-.86	-1.08	-.08	-2.00	80	39
5	.61	-.01	.32	.95	.91	.15	101	83
6	.96	-1.24	1.10	-1.09	.24	-.71	82	68
F	181.7	183.2	183.4	162.6	212.4	253.0		
df	5	5	5	5	5	5		
p	.001	.001	.001	.001	.001	.001		

Note. *g* = General Cognitive Ability. S1 = Sample 1. S2= Sample 2. No adjustments for multiple testing were made. *p* value as derived from ANOVA.

Table 3.13

Four-cluster solution cluster centre means of the k-means non-iterative partitioning with random starting seed points for Samples 1 and 2.

Cluster	Cluster centre means							
	Memory		*g*		Speed		n	
	S1	S2	S1	S2	S1	S2	S1	S2
Initial seed points								
1	1.12	1.28	-.16	-.32	-2.43	-1.13		
2	-2.44	-2.58	-2.04	-2.09	-3.00	-2.71		
3	-1.29	1.39	-.86	2.70	1.26	1.73		
4	1.40	-2.90	2.60	-.72	1.05	1.92		
Final cluster solution								
1	.49	.52	-.19	-.12	-.62	-.39	109	157
2	-1.01	-1.03	-1.09	-1.09	-1.10	-1.26	76	100
3	-.59	.66	.04	.92	.57	.74	139	141
4	.81	-.85	.78	-.05	.61	.62	166	118

Note. g = General Cognitive Ability. S1 = Sample 1. S2= Sample 2.

Table 3.14

Six-cluster solution centre means of the k-means non-iterative partitioning with random seed points for Samples 1 and 2.

Cluster	Cluster centre means							
	Memory		*g*		Speed		n	
	S1	S2	S1	S2	S1	S2	S1	S2
Initial seed points								
1	-2.38	.69	.72	-1.44	.96	.03		
2	-2.44	-2.53	-2.04	-.10	-3.00	2.19		
3	1.12	1.80	-.16	1.73	-2.43	1.73		
4	-.12	-1.08	-1.38	-2.20	.21	-3.00		
5	1.13	-.26	.92	1.53	2.01	-.38		
6	1.21	-2.48	2.15	-1.19	-.60	-.65		
Final cluster solution								
1	-.66	-.52	.48	-.25	.62	-.39	87	134
2	-.96	-.89	-1.22	-.05	-1.82	.76	38	94
3	.49	.98	-.18	.74	-.61	.88	102	98
4	-.86	-.63	-.86	-1.08	-.08	-2.00	80	39
5	.61	-.01	.32	.95	.91	.15	101	83
6	.96	-1.24	1.10	-1.09	.24	-.71	82	68

Note. g = general cognitive ability. S1 = Sample 1. S2= Sample 2.

Table 3.15

Raw means of Age 70 IQ and Spatial span for each of the four clusters in the 4-cluster solution in Samples 1 and 2 with significance values as derived from ANOVA.

	Cluster 1		Cluster 2		Cluster 3		Cluster 4		df	F	*p*
Sample 1	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Age 70 IQ	108.93	6.94	101.53	11.68	101.39	12.09	82.77	15.78	3	93.88	.001
Spatial span	16.07	2.66	14.81	2.65	14.03	2.39	12.83	2.06	3	33.05	.001
Sample 2											
Age 70 IQ	109.09	7.24	102.54	11.15	98.99	12.93	84.94	15.54	3	85.01	.001
Spatial Span	16.07	2.57	14.72	2.30	15.13	2.90	12.83	2.59	3	31.62	.001

Table 3.16

Raw means of Age 70 IQ and Spatial span for each of the six clusters in the 6-cluster solution in Samples 1 and 2, with significance values as derived from ANOVA.

	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5		Cluster 6		df	F	*p*
Sample 1	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Age-70 IQ	111.5	6.4	106.1	7.0	104.1	10.5	102.1	11.6	90.3	13.6	78.6	16.5	5	70.1	.001
Spatial Span	16.6	2.4	15.4	2.8	15.7	2.3	13.9	2.4	13.1	2.4	12.9	2.1	5	27.3	.001
Sample 2															
Age-70 IQ	108.4	7.5	109.5	7.2	98.7	13.1	100.9	11.7	82.5	17.4	85.5	13.9	5	54.2	.001
Spatial Span	16.0	2.6	15.8	2.6	15.3	2.8	14.6	2.3	12.5	2.6	13.0	2.6	5	20.7	.001

Table 3.17
Standardised means of g, Memory, and Speed with standard deviations (SD) for each of 4 clusters in sub-samples 1 and 2.

	g	SD	Memory	SD	Speed	SD	N	%
Sample 1								
1	.78	.61	.81	.54	.61	.55	166	34
2	.04	.67	-.59	.59	.57	.52	139	28
3	-.19	.56	.50	.50	-.62	.56	109	22
4	-1.09	.57	-1.01	.62	-1.10	.86	76	16
N							490	100
Sample 2								
1	.92	.62	.66	.64	.74	.55	141	27
2	-.05	.65	-.85	.62	.62	.55	118	24
3	-.12	.54	.52	.59	-.39	.54	157	30
4	-1.09	.61	-1.03	.75	-1.26	.75	100	19
N							516	100

Note. *g* = general cognitive ability. SD = standard deviation.

Table 3.18

Standardised means of g, Memory, and Speed with standard deviations (SD) for each of 6 clusters in samples 1 and 2.

	g	SD	Memory	SD	Speed	SD	N	%
Sample 1								
1	1.10	.48	.96	.57	.31	.69	82	16.7
2	.32	.56	.61	.45	.73	.58	101	20.6
3	.48	.50	-.66	.53	.56	.65	87	17.8
4	-.18	.52	.49	.50	-.53	.57	102	20.8
5	-.86	.45	-.86	.60	-.18	.67	80	16.3
6	-1.22	.64	-.96	.72	-1.66	.84	38	7.8
N							490	100
Sample 2								
1	.74	.70	.98	.53	.79	.57	98	19.1
2	.95	.44	-.01	.50	.25	.66	83	16.1
3	-.05	.54	-.89	.64	.61	.60	94	18.2
4	-.25	.50	.52	.57	-.25	.64	134	26.1
5	-1.08	.69	-.63	.78	-1.87	.88	39	7.6
6	-1.09	.56	-1.24	.65	-.72	.71	68	13.2
N							516	100

Note. g = general cognitive ability. SD = standard deviation.

Table 3.19

Model information criteria for each of the two-, three-, four- and five-group solutions.

Group-solution	AIC	BIC	Adjusted BIC
Two	6326.19	6376.14	6344.38
Three	6194.57	6264.50	6220.03
Four	6147.10	6237.01	6179.83
Five	6123.30	6233.19	6163.31
Six	6097.43	6227.15	6144.57

Note. AIC = Akaike information criterion. BIC = Bayesian information criterion. Adjusted BIC = (n* = (n* = (n + 2) / 24).

Table 3.20

Probability of falling into a latent group by cognitive ability measures in the Lothian Birth Cohort 1936.

Class	N	Probability of group 1	Probability of group 2	Probability of group 3	Total
1	749	0.10	0.90	0.00	100%
2	303	0.81	0.16	0.02	100%
3	39	0.14	0.04	0.82	100%

Table 3.21
Means and significance values as derived from ANOVA of cognitive measures (standard deviations in parentheses) for each of the latent groups of the Lothian Birth Cohort 1936.

Group	N (%)	*g*	Memory	Speed
High Cognition	749 (69)	.30 (0.6)	.40 (0.5)	.13 (0.4)
Average Cognition	303 (28)	-.60 (0.6)	-.84 (0.6)	-.06 (0.4)
Low Cognition	39 (4)	-1.03 (0.5)	-.74 (0.9)	-1.56 (0.6)
df		2, 1088	2, 1088	2, 1088
F		339.69	566.65	278.56
p		.001	.001	.001

Note. *g* = general cognitive ability.

Table 3.22
Raw means, standard deviations (SDs) and significance values as derived from ANOVA of age 11 IQ, NART, and number of years in formal education for each of the 3 groups in the Lothian Birth Cohort 1936.

Variables	High Cognition		Average Cognition		Low Cognition				
	Mean	SD	Mean	SD	Mean	SD	df	F	*p*
Age-11 IQ	104.7	12.9	90.2	13.8	82.5	14.1	2	152.8	.001
NART	37.2	6.8	29.1	7.7	25.2	8.2	2	172.7	.001
Years of Education	11.0	1.2	10.3	0.8	10.1	0.8	2	50.9	.001

Note. NART = National Adult Reading Test. No adjustment of significance levels for multiple testing.

Table 3.23

Proportions, percentages and significance values in sex, marital status, living status, and social class status for each of the 3 groups in the Lothian Birth Cohort 1936.

Variables	High		Average		Low				
	n	%	n	%	n	%	df	X^2	*p*
Sex									
Males	361	48.2	156	51.5	31	79.5			
Females	388	51.8	147	48.5	8	20.5			
N	749	100	303	100	39	100	2	14.7	.001
Marital Status									
Married	548	73.2	208	68.6	22	56.4			
Single	45	6.0	17	5.6	3	7.7			
Divorced	49	6.5	34	11.2	1	2.6			
Cohabiting	12	1.6	5	1.7	0	0			
Widowed	95	12.7	39	12.9	12	30.8			
Other	0	0	0	0	1	2.6			
N	749	100	303	100	39	100	10	46.4	.001
Living Status									
Alone	174	23.2	78	25.7	14	35.9			
Not alone	575	76.8	225	74.3	25	64.1			
N	749	100	303	100	39	100	2	3.65	.16
Social Class									
I	169	22.6	21	6.9	0	0			
II	291	38.9	105	34.7	6	15.4			
III (non manual)	161	21.5	75	24.8	10	25.6			
III (manual)	93	12.4	78	25.7	17	43.6			
IV	22	2.9	12	4.0	4	10.3			
V	2	0.3	2	0.7	2	5.1			
N	738	98.5	293	96.7	39	100	10	104.5	.001

Note. No adjustment for multiple testing.

Table 3.24

Tukey's HSD post-hoc results for age 11 IQ, NART, years in education, sex, marital status and social class.

Variables	Compare	Effect size (Cohen's *d*)	Mean difference	Confidence interval	
				Lower	Higher
Age-11 IQ	1-2	1.09	14.5***	12.3	16.7
	1-3	1.64	22.2***	16.8	27.5
	2-3	0.57	7.7**	2.1	13.2
NART	1-2	1.12	8.0***	7.0	9.2
	1-3	1.60	12.0***	9.2	14.7
	2-3	0.49	4.0**	1.1	6.8
Yrs. Educ.	1-2	0.70	1.1***	0.5	0.9
	1-3	0.90	1.1***	0.5	1.3
	2-3	0.25	0.2	-0.2	0.6
Sex	1-2	0.06	.03	-.05	.11
	1-3	0.68	.31***	.12	.50
	2-3	0.62	.28**	.08	.48
Marital Status	1-2	0.06	1.00	-.33	.13
	1-3	0.45	.74**	-1.29	-.19
	2-3	0.39	-.64*	-1.21	-.08
Social Class	1-2	0.50	.44***	-.58	-.30
	1-3	1.26	1.02***	-1.36	-.69
	2-3	0.76	.58***	-.93	-.23

Note. * $p < .05$ ** $p < .01$ *** $p < .001$.NART= National Adult Reading Test. Yrs. Educ. = total number of years in formal education. 1= High Cognition. 2 = Average Cognition. 3 = Low Cognition.

Table 3.25

Odd ratios (OR) for group membership for the demographic and prior cognitive ability measures in the Lothian Birth Cohort 1936, with 95% confidence intervals (CI).

Variables	OR	95% CI		OR	95% CI	
	Average Cognition	Lower	Upper	Low Cognition	Lower	Upper
Sex, males	1.09	.77	1.53	3.11**	1.48	6.53
Yrs. of Education	.83*	.70	.98	1.02	.71	1.46
Age-11 IQ	.94***	.93	.96	.92***	.90	.94
NART	.87***	.85	.89	.84***	.80	.88
Marital Status, not married	.93	.78	1.11	1.45**	1.13	1.86
Living Status, not alone	1.29	.73	2.29	1.05	.42	2.61
Social Class, low	1.14	.95	1.37	2.55***	1.56	4.15

Note. The High Cognition group was used as baseline. NART = National Adult Reading Test. * $p < .05$ ** $p < .01$ *** $p < .001$.

Table 3.26

Raw means, standard deviations (SDs), and significance values as derived from ANOVA for neuroticism, extraversion, openness, agreeableness, and conscientiousness in the 3 groups representing Cognitive Ability in the Lothian Birth Cohort 1936.

Variables	High Cognition		Average Cognition		Low Cognition				
	Mean	SD	Mean	SD	Mean	SD	df	F	*p*
Neuroticism	16.6	7.6	18.3	7.5	19.0	7.3	2	5.3	.005
Extraversion	27.1	6.0	26.8	5.9	24.8	5.2	2	2.1	.123
Openness	27.0	5.8	23.9	5.0	22.7	5.3	2	32.8	.000
Agreeableness	33.8	5.3	33.0	5.2	30.4	4.3	2	7.3	.001
Conscientiousness	34.8	6.1	34.5	5.6	33.7	5.3	2	.54	.584

Note. No adjustment of significance levels for multiple testing.

Table 3.27

Tukey's HSD post-hoc results for neuroticism, openness, and agreeableness.

Effect	Compare	Effect size (Cohen's *d*)	Mean difference	Confidence Interval	
				Lower	Higher
Neuroticism	1-2	0.23	1.67**	-2.98	-0.36
	1-3	0.32	2.38	-5.87	1.11
	2-3	0.10	0.71	-4.31	2.89
Openness	1-2	0.57	3.10***	2.13	4.08
	1-3	0.78	4.30***	1.71	6.89
	2-3	0.23	1.19	-1.48	3.67
Agreeableness	1-2	0.15	.84	-.06	1.74
	1-3	0.02	3.41**	1.00	5.82
	2-3	0.13	2.57*	0.09	5.05

Note. 1 = High Cognition. 2 = Average Cognition. 3 = Low Cognition * p < .05 ** *p* < .01 *** *p* < .001.

Table 3.28

Odd ratios (OR) for group membership for the personality measures of Lothian Birth Cohort 1936, with 95% confidence interval (CI).

Variable	OR	95% CI		OR	95% CI	
	Average	Lower	Upper	Low	Lower	Upper
Neuroticism	1.04***	1.01	1.06	1.01	0.95	1.07
Extraversion	1.03	1.00	1.06	0.98	0.91	1.06
Openness	0.90***	0.88	0.93	0.89***	0.82	0.96
Agreeableness	0.99	0.96	1.02	0.90**	0.83	0.97
Conscientiousness	1.00	0.98	1.03	1.00	0.92	1.08

Note. The High Cognition group is baseline. OR = Odds Ratio. CI = Confidence Interval. ** $p < .01$ *** $p < .05$

Table 3.29

Raw means, standard deviations, and significance values as derived from ANOVA, of scores from the HADS, and ADLs and of level of physical activity for the 3 groups in the Lothian Birth Cohort 1936.

Variables	High Cognition		Average Cognition		Low Cognition				
	Mean	SD	Mean	SD	Mean	SD	df	F	*p*
HADS (D)	2.78	2.3	2.94	2.2	2.13	1.7	2	2.36	.659
HADS (A)	4.94	3.2	4.82	3.3	4.54	2.9	2	.42	.095
ADLs	1.00	2.0	1.05	2.0	.59	1.2	2	.94	.391
Level of physical activity	3.00	1.1	3.00	1.1	3.11	1.0	2	.38	.683

Note. HADS (D) = Hospital Anxiety and Depression Scales (Depression). HADS (A) = Hospital Anxiety and Depression Scales (Anxiety). ADLs = Activities of Daily Living.

Table 3.30

Odd ratios (OR) for group membership for physical and mental well being in the Lothian Birth Cohort 1936, with 95% confidence intervals (CI).

Variable	OR Average	95% CI		OR Low	95% CI	
		Lower	Upper		Lower	Upper
HADS (D)	1.04	.93	1.03	0.99	.88	1.11
HADS (A)	0.98	.97	1.12	0.85	.69	1.06
ADLs	0.97	.89	1.06	0.94	.73	1.20
Physical activity	1.03	.90	1.18	1.06	.77	1.44

Note. The High Cognition group is baseline. OR = odds ratio. CI = Confidence interval. HADS (D) = Hospital Anxiety and Depression Scales (Depression). HADS (A) = Hospital Anxiety and Depression Scales (Anxiety). ADLs = Activities of Daily Living.

Table 3.31

Raw means, standard deviations (SDs) and significance values as derived from ANOVA for health measures for each of the 3 groups in the Lothian Birth Cohort 1936.

Variables	High Cognition		Average Cognition		Low Cognition				
	Mean	SD	Mean	SD	Mean	SD	df	F	*p*
BMI	27.6	4.3	28.1	4.5	29.1	4.4	2	3.62	.027
Units alcohol/week	11.2	14.8	8.5	12.2	12.3	15.7	2	4.27	.014

Note. BMI = body mass index. No adjustment of significance levels for multiple testing.

Table 3.32

Proportions, percentages and significance values for APOE e4 allele and smoking status in the 3 groups in the Lothian Birth Cohort 1936.

Variables	High		Average		Low				
	N	%	N	%	N	%	df	X^2	*p*
*APOE*e4									
Not present	498	71.1	201	69.3	23	60.5			
Present	202	28.9	89	30.7	15	39.5			
N	700		290		38		2	2.11	.359
Smoking category									
Never smoked	328	43.8	130	42.9	16	41			
Ex-Smoker	334	44.6	123	40.6	14	35.9			
Current smoker	87	11.6	50	16.5	9	23.1			
N	749		303		39		4	8.08	.089

Note. APOEe4 = Apolipoprotein E allele 4.

Table 3.33

Tukey's HSD post-hoc results on BMI and Units of alcohol per week.

	Compare	Effect size (Cohen's *d*)	Mean difference	95% confidence interval	
				Lower	Higher
BMI	1-2	0.11	0.57	-1.26	.13
	1-3	0.35	1.50	-3.18	.17
	2-3	0.23	.93	-2.67	.80
Units alcohol/week	1-2	0.20	2.71*	.45	4.97
	1-3	0.07	1.02	-6.48	4.42
	2-3	0.27	3.74	-9.38	1.91

Note. BMI = Body Mass Index. 1 = High Cognition. 2 = Average Cognition. 3 = Low Cognition. * $p < .05$.

Table 3.34

Odds ratios (ORs) for group membership for the health measures in the Lothian Birth Cohort 1936 sample with 95% confident intervals (CI).

Variable	OR Average	95% CI		OR Low	95% CI	
		Lower	Upper		Lower	Upper
APOEe4	1.11	.82	1.50	1.67	.85	3.28
BMI, high	1.03*	1.00	1.06	1.07	1.00	1.15
Smoking category, smoker	1.00	.96	1.43	1.44	.90	2.32
Drinks units/week	0.98**	.97	1.00	1.07	.98	1.02

Note. The High Cognition group is baseline. BMI = body mass index. APOEe4 = Apolipoprotein E allele 4. OR = odds ratio. CI = confidence interval. * $p < .05$ ** $p < .01$

Table 3.35

Raw means, standard deviations (SDs), and significance values as derived from ANOVA of quality of life for each of the 3 groups in the Lothian Birth Cohort 1936.

Variables	High Cognition		Average Cognition		Low Cognition				
	Mean	SD	Mean	SD	Mean	SD	df	F	*p*
Physical	16.13	2.6	16.00	2.7	16.33	2.0	2	.349	.706
Psychological	15.66	1.8	15.61	1.9	16.27	1.4	2	2.203	.111
Social	17.18	2.3	17.09	2.3	16.85	2.3	2	.419	.658
Environmental	16.72	1.8	16.6	1.9	17.19	.3	2	1.626	.197

Table 3.36
Odds ratios (ORs) for group membership for the quality of life measures in the Lothian Birth Cohort 1936 sample with 95% confident interval (CI).

Variables	OR Average	95% CI		OR Low	95% CI	
		Lower	Upper		Lower	Upper
Physical	0.99	.92	1.06	0.94	.80	1.09
Psychological	1.00	.90	1.13	1.37	1.05	1.79
Social	0.99	.92	1.07	0.82	.70	.96
Environmental	0.98	.89	1.08	1.14	.90	1.46

Note. The High Cognition group is baseline. OR = odds ratio. CI = confidence interval.

Table 3.37
Standardised means, standard deviations (SDs) and significance values as derived from ANOVA for physical measures for each of the 3 groups in the Lothian Birth Cohort 1936.

Variables	High Cognition		Average Cognition		Low Cognition				
	Mean	SD	Mean	SD	Mean	SD	df	F	*p*
FEV_1	.01	1.0	-.05	1.0	-.14	.9	2	.745	.475
FVC	.01	1.0	-.04	1.0	-.10	.9	2	.527	.591
6m walk-time	0	1.0	0	1	-.12	1.0	2	.347	.707
Grip strength	.02	1	-.06	1	-.08	.9	2	.854	.426

Note. FEV_1 = forced expiratory volume in 1 second. FVC = forced vital capacity. 6 m = 6 meters. All variables here have been adjusted for sex, by saving the standardised residual from a linear regression with height as the independent variable and each of the above variables as the dependent variable.

Table 3.38

Odds ratios (ORs) for group membership for physical measures in the Lothian Birth Cohort 1936 with 95% confidence intervals (CI).

Variable	OR Average	CI 95%		OR Low	CI 95%	
		Lower	Higher		Lower	Higher
FEV_1	0.97	.77	1.22	1.22	.68	2.19
FVC	0.99	.79	1.25	0.94	.53	1.66
6m walk-time	0.98	.85	1.13	1.17	.88	1.55
Grip strength	0.93	.80	1.08	1.05	.74	1.49

Note. The High Cognition group is baseline. OR = odds ratio. CI = confidence interval. FEV_1 = forced expiratory volume in 1 second. FVC = Forced Vital Capacity. 6m = 6 meters.

Table 3.39

Proportions, percentages and significance values for disease status in the 3 groups in the Lothian Birth Cohort 1936.

Variables	High Cognition		Average Cognition		Low Cognition				
	N	%	N	%	N	%	df	X^2	*p*
High BP									
Yes	295	39.4	123	40.6	15	38.5			
No	454	60.6	180	59.4	24	61.5			
N	749	100	303	100	39	100	2	.157	.925
Diabetes									
Yes	60	8	29	9.6	2	94.9			
No	689	92	274	90.4	37	5.1	2	1.233	.540
N	749	100	303	100	39	100			
CVD									
Yes	165	22	95	31.4	8	20.5			
No	584	78	208	68.6	31	79.5			
N	749	100	303	100	39	100	2	10.479	.005
Circulation Problems									
Yes	101	13.5	49	83.8	6	15.4			
No	646	86.2	253	16.2	33	84.6			
N	747	100	302	100	39	100	2	1.317	.518
Stroke									
Yes	30	4	20	6.6	4	10.3			
No	719	96	283	93.4	35	89.7			
N	749	100	303	100	39	100	2	5.510	.064

Note. BP = blood pressure. CVD = cardiovascular disease. *Note.* No adjustment of significance levels for multiple testing.

Table 3.40

Tukey's HSD post-hoc results for history of cardiovascular disease (CVD).

Effect	Compare	Effect size (Cohen's *d*)	Mean difference	95% confidence interval	
				Lower	Higher
History of CVD	1-2	0.20	.09**	-.16	-.02
	1-3	0.03	.02	-.15	.18
	2-3	0.23	.11	-.06	.28

Note. CVD = cardiovascular disease. *Note.* 1 = High Cognition. 2 = Average Cognition. 3 = Low Cognition. ** $p < .05$.

Table 3.41

Odds ratios for group membership for physical measures in the Lothian Birth Cohort 1936 sample with 95% confident interval (CI).

Variable	OR Average Cognition	Confidence Interval 95%		OR Low Cognition	Confidence Interval 95%	
		Lower	Higher		Lower	Higher
High BP	0.94	.70	1.25	0.97	.49	1.93
Diabetes	1.06	.65	1.72	0.54	.12	2.41
CVD	1.62***	1.19	2.21	0.93	.41	2.11
Circulation problems	1.26	.87	1.83	1.16	.47	2.84
Stroke	1.66*	.92	3.01	3.02*	.99	9.26

Note. OR = odds ratio. BP = blood pressure. CVD = cardiovascular disease. * $p < .05$ *** $p < .001$

Table 3.42

Raw means, standard deviations (SDs) and significance values as derived from ANOVA for total number of medication and number of medical conditions for each of the 3 groups in the Lothian Birth Cohort 1936.

Variables	High Cognition		Average Cognition		Low Cognition				
	Mean	SD	Mean	SD	Mean	SD	df	F	*p*
Medication total	2.8	2.4	3.3	2.6	3.8	2.9	2	6.105	.002
Medical conditions	3.1	1.7	3.3	1.7	3.6	2.4	2	1.565	.210

Note. No adjustment of significance levels for multiple testing.

Table 3.43

Effect	Compare	Effect size	Mean difference	95% confidence interval	
				Lower	Higher
Number of medications	1-2	0.20	.48*	-.89	-.09
	1-3	0.33	.41	-1.93	.00
	2-3	0.15	.43	-1.48	.53

Tukey's HSD post-hoc results on total amount of medication taken and total number of medical conditions.

Note. 1 = High Cognition. 2 = Average Cognition. 3 = Low Cognition. * $p < .05$

Table 3.44

Odd ratios (OR) for group membership for medication and medial conditions of LBC1936 participants, with 95% confidence interval (CI).

Variable	OR Low Cognition	Confidence Interval 95%		OR Average Cognition	Confidence Interval 95%	
		Lower	Higher		Lower	Higher
Drugs total	1.10**	1.03	1.18	1.16*	.99	1.35
Medical conditions	0.96	.87	1.06	1.01	.80	1.27

Note. OR = odds ratio. * $p < .05$ ** $p < .01$

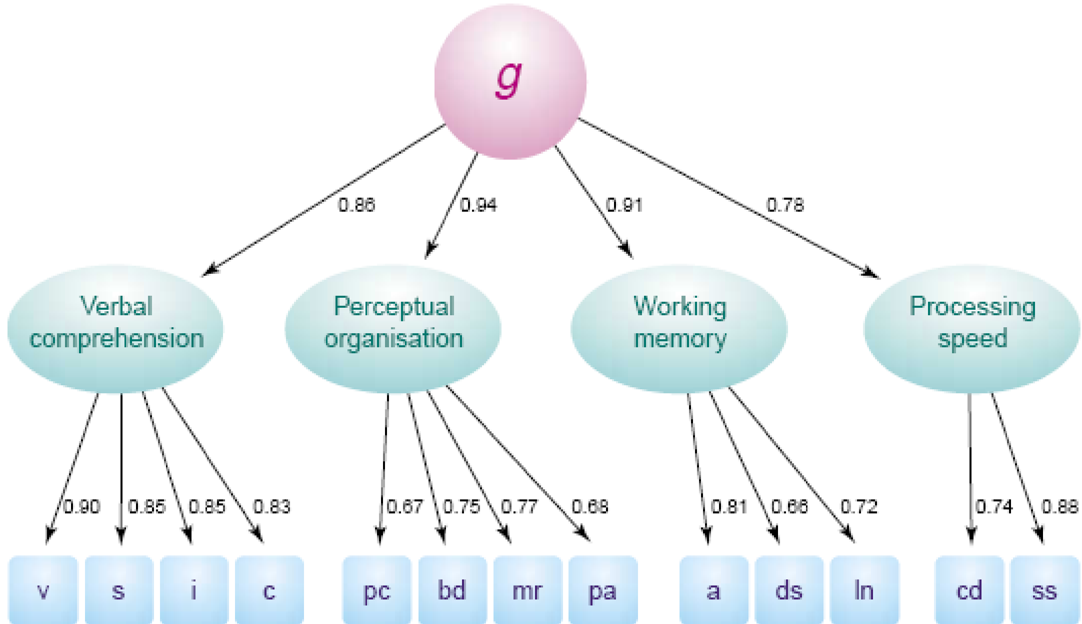


Figure 3.1: The three-stratum model of intelligence as proposed by Carroll (1993), where the specific tests are found at the bottom stratum, higher factor loadings at the second level, and the general (*g*) factor at the very top. Adapted from Deary (2001), who applied and analysed the WAIS sub-tests (Wechsler, 1997) in accordance with this model on the American standardisation sample of Wechsler Adult Intelligence Scale-III (WAIS-III). Abbreviations: v - vocabulary; s - similarities; i - information; c - comprehension; pc - picture completion; bd - block design; mr - matrix reasoning; pa - picture arrangement; a - arithmetic; ds, digit span; ln - letter–number sequencing; cd - digit-symbol coding; ss - symbol search.

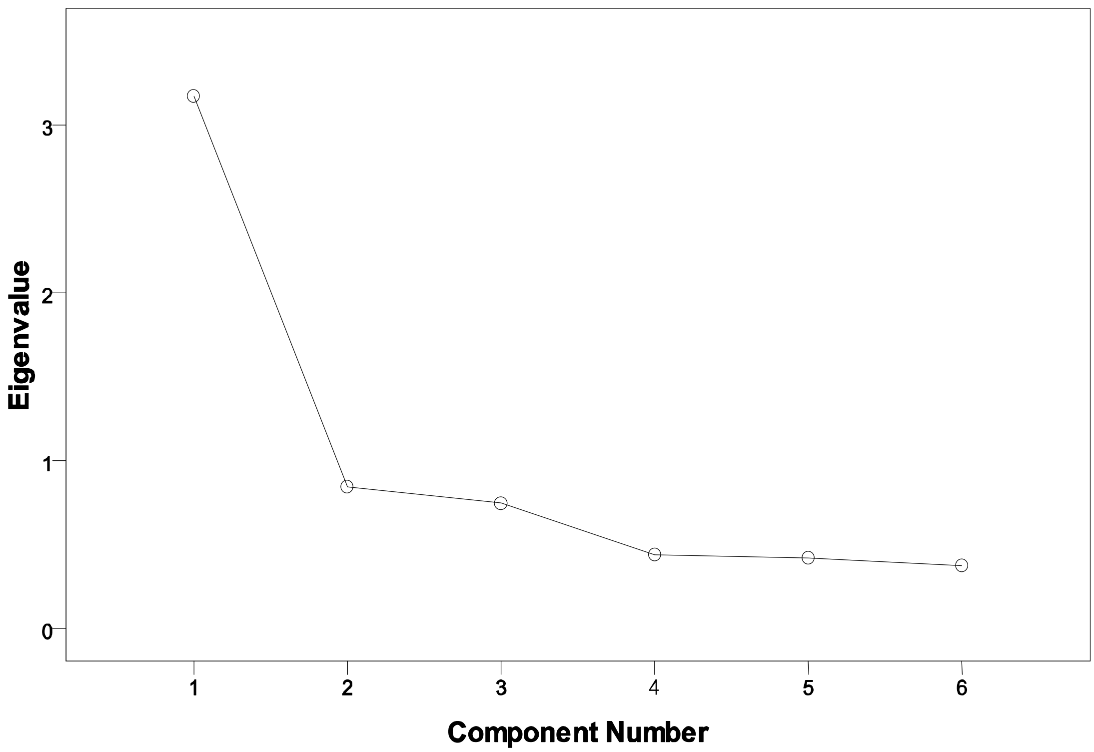


Figure 3.2. The scree plot for general cognitive intelligence displaying inflexions that would justify retaining one component.

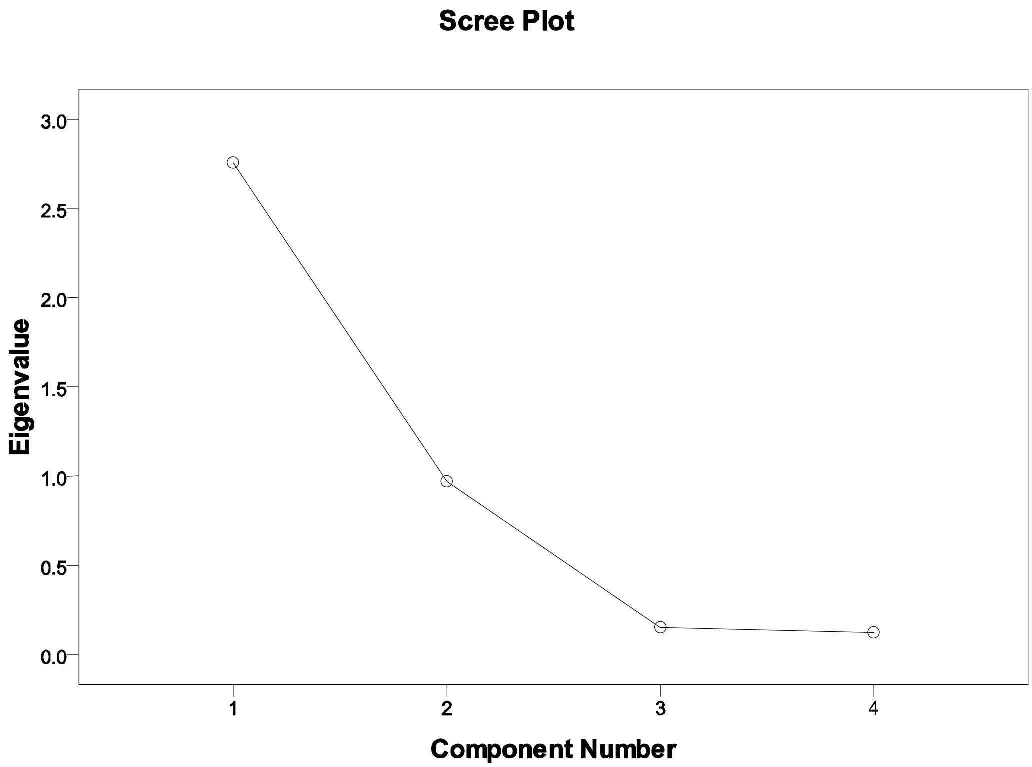


Figure 3.3. The scree plot for memory displaying inflexions that would justify retaining one component.

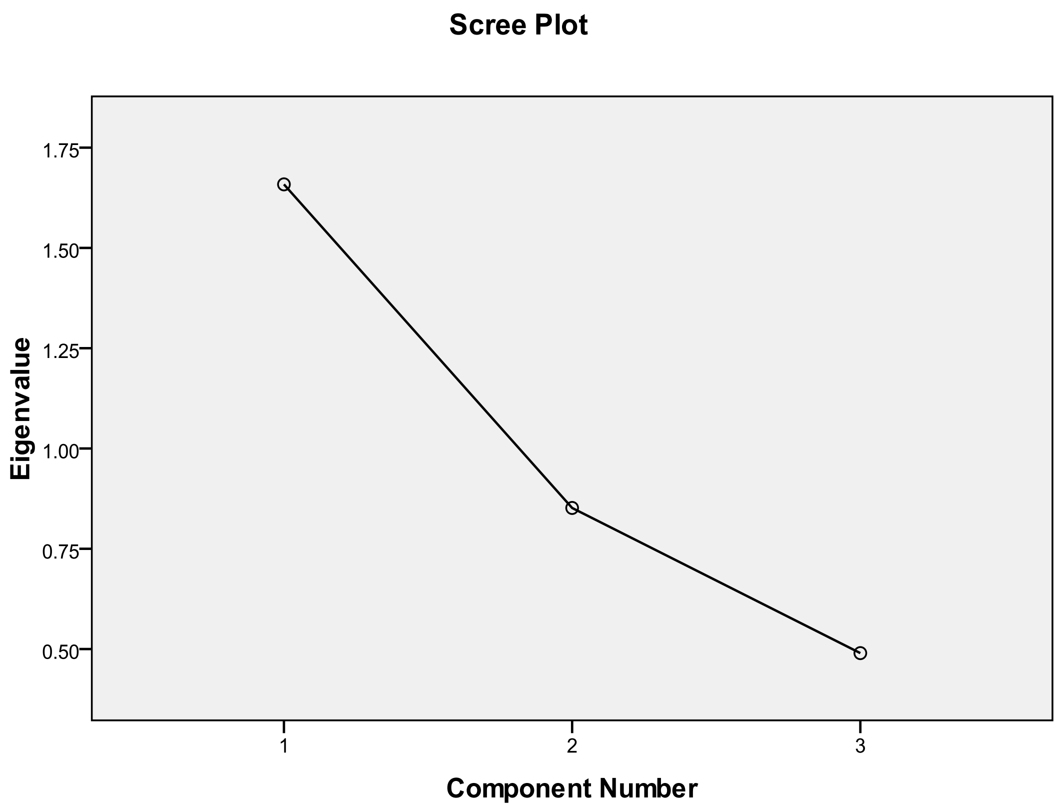


Figure 3.4. The scree plot for speed displaying inflexions that would justify retaining one component.

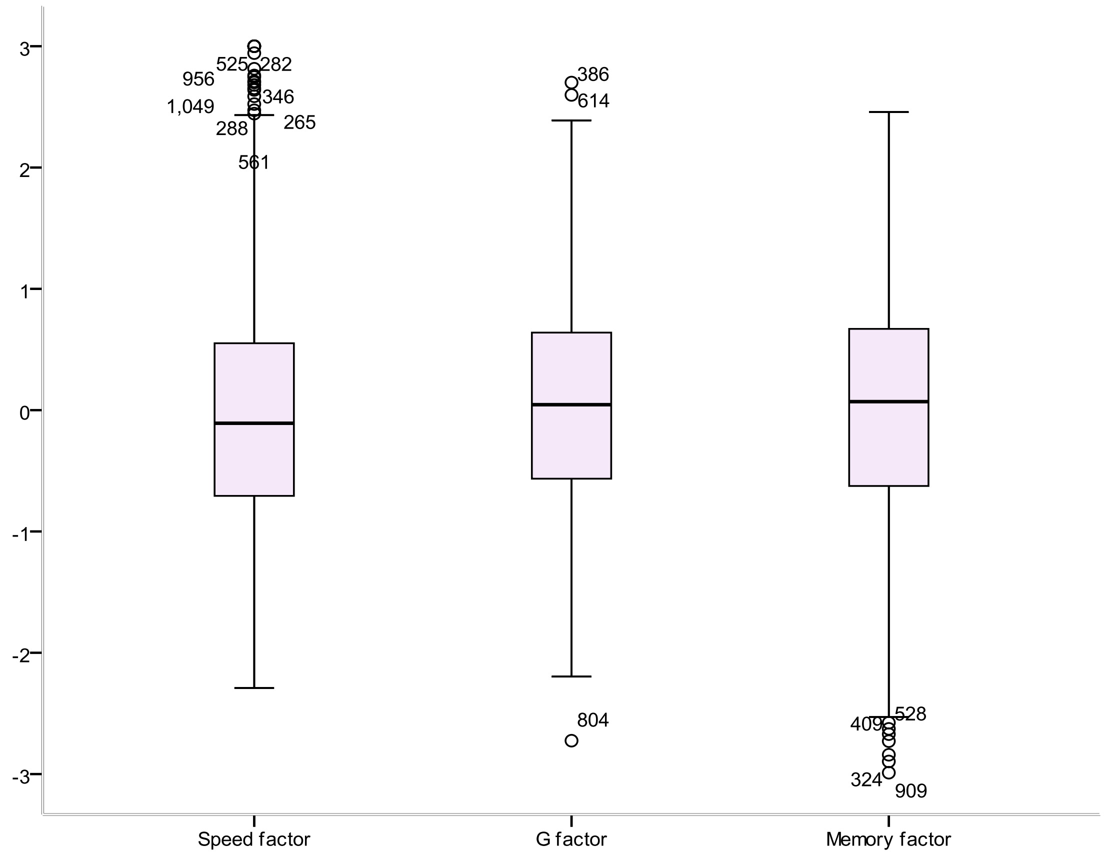


Figure 3.5. The boxplots of the cognitive components retained from principal components analysis with winsorized scores.

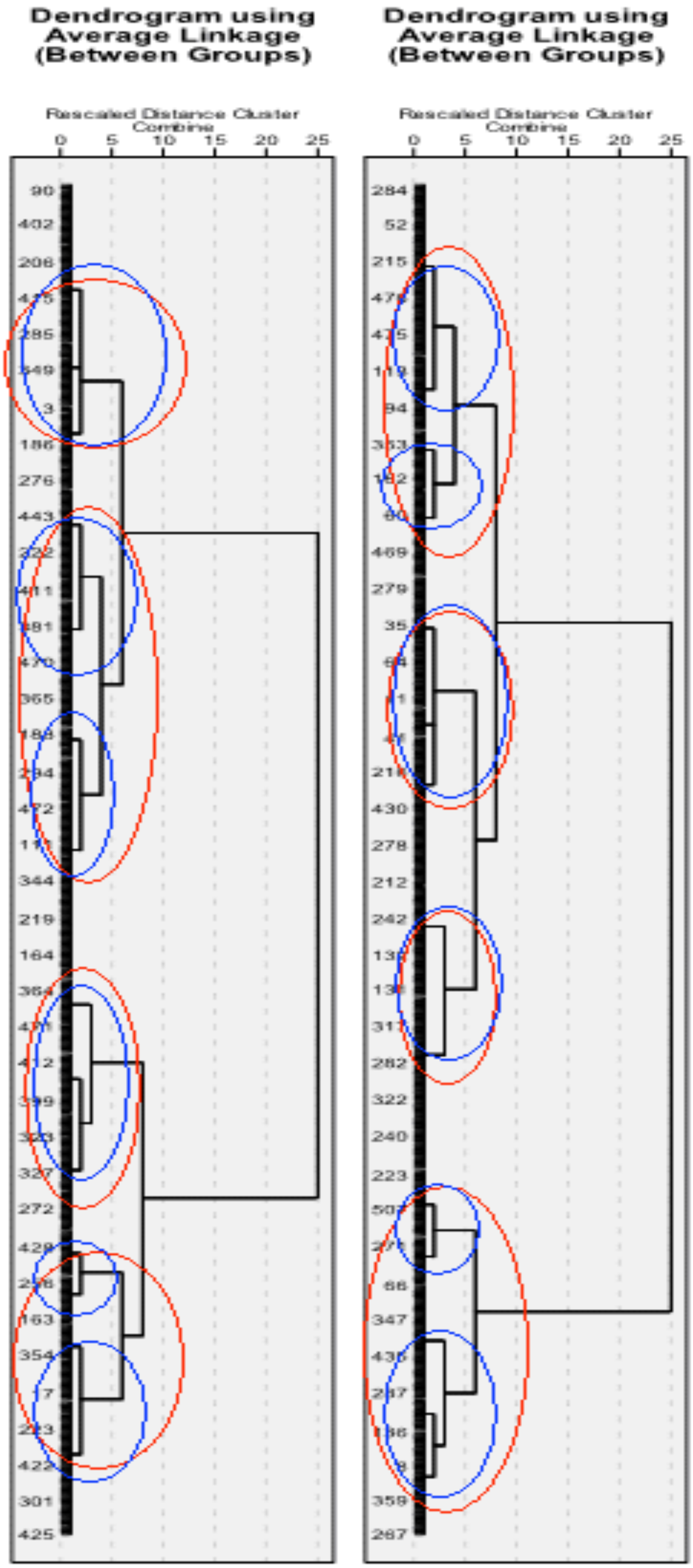


Figure 3.6. The dendrograms derived from cluster analysis using Ward's Method for Samples 1 (left) and 2 (right). The y-axis shows the case numbers, and the x-axis shows the level of similarity the groups shared. Higher points reflect a higher level of similarity. I inserted red and blue circles to indicate what I thought seemed like a possible 4- or 6-cluster solution.

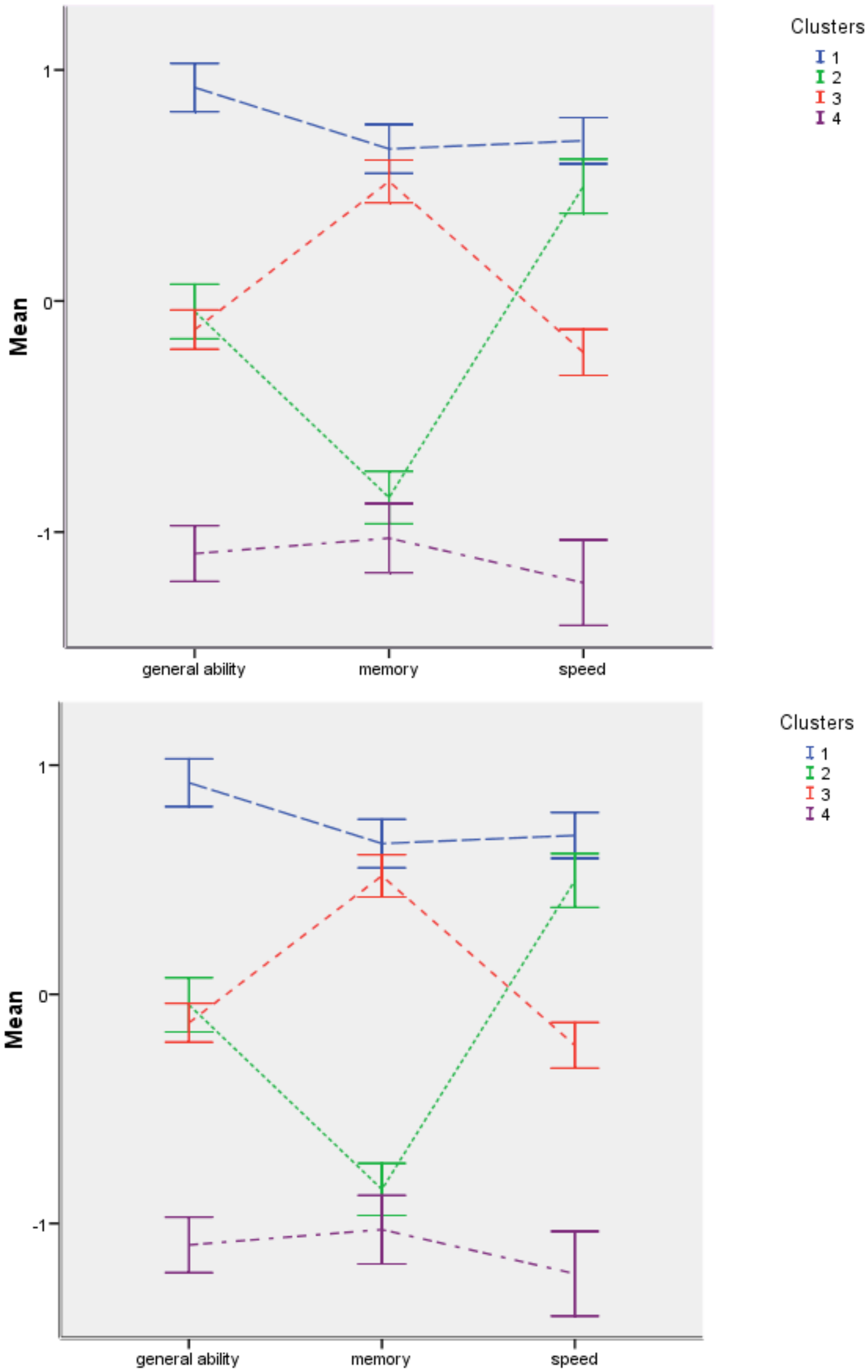


Figure 3.7. The clusters' mean scores for the 4-cluster solution on each of the cognitive factors, namely *g,* Memory, and Speed, with 95% confidence interval, for samples 1 (top) and 2 (bottom). Note the similarity between the two figures.

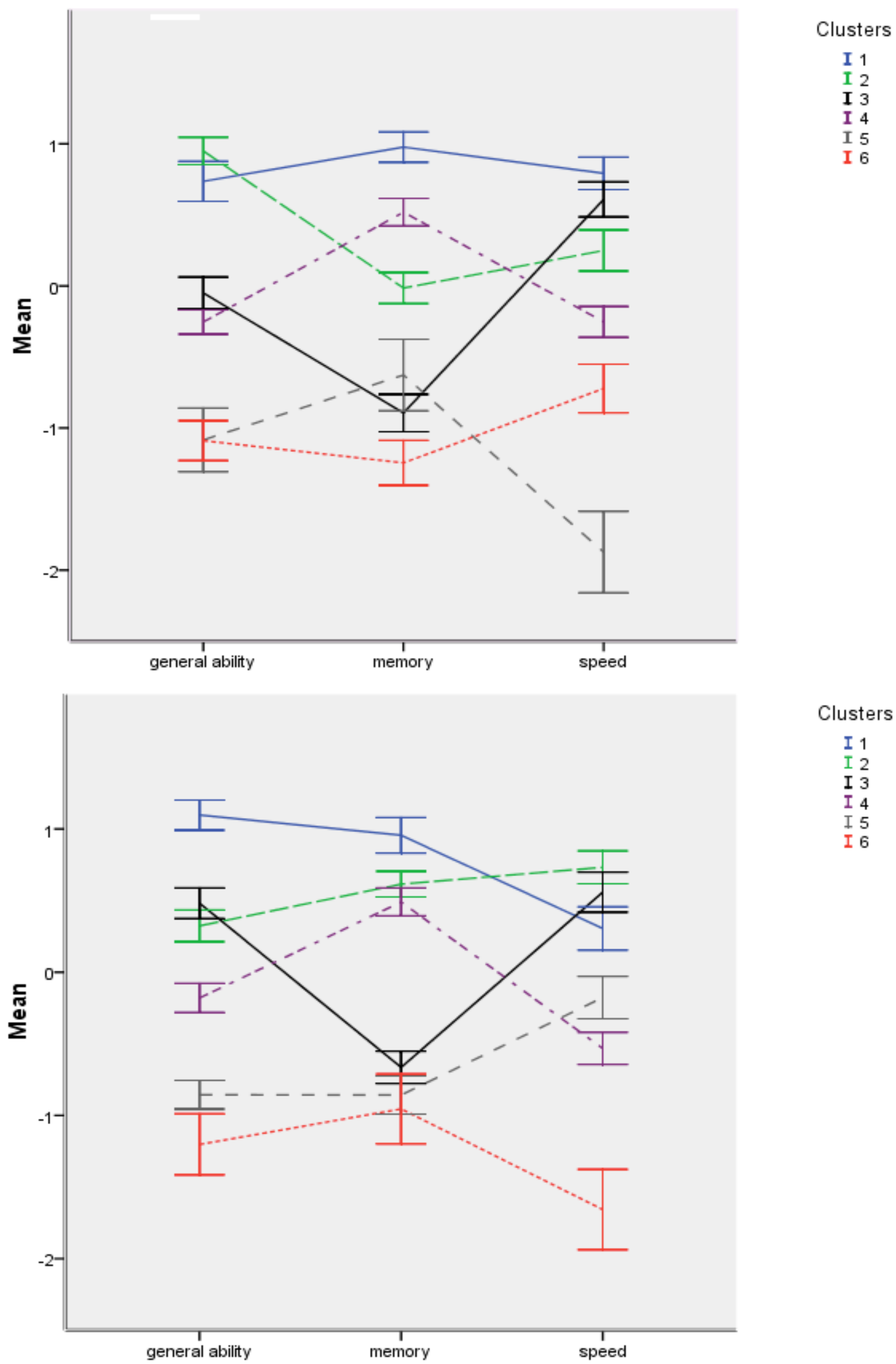


Figure 3.8. The clusters' mean scores for the 6-cluster solution on each of the cognitive factors, namely *g*, Memory, and Speed, with 95% confidence interval, for samples 1 (top) and 2 (bottom).

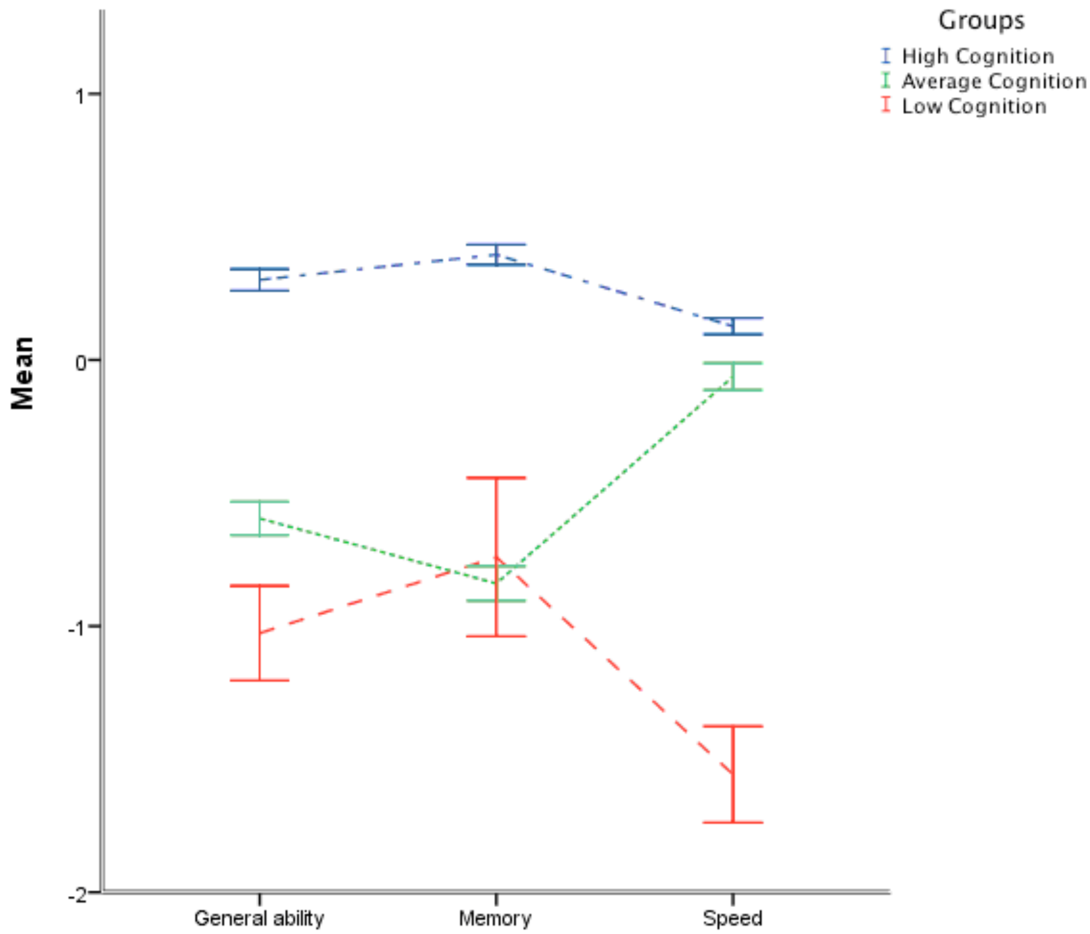


Figure 3.9. The groups' mean scores on each of the cognitive components, *g*, Memory, and Speed, for the 3-group solution, with two error bars at 95% confidence intervals, as generated from latent class analysis for the Lothian Birth Cohort 1936.

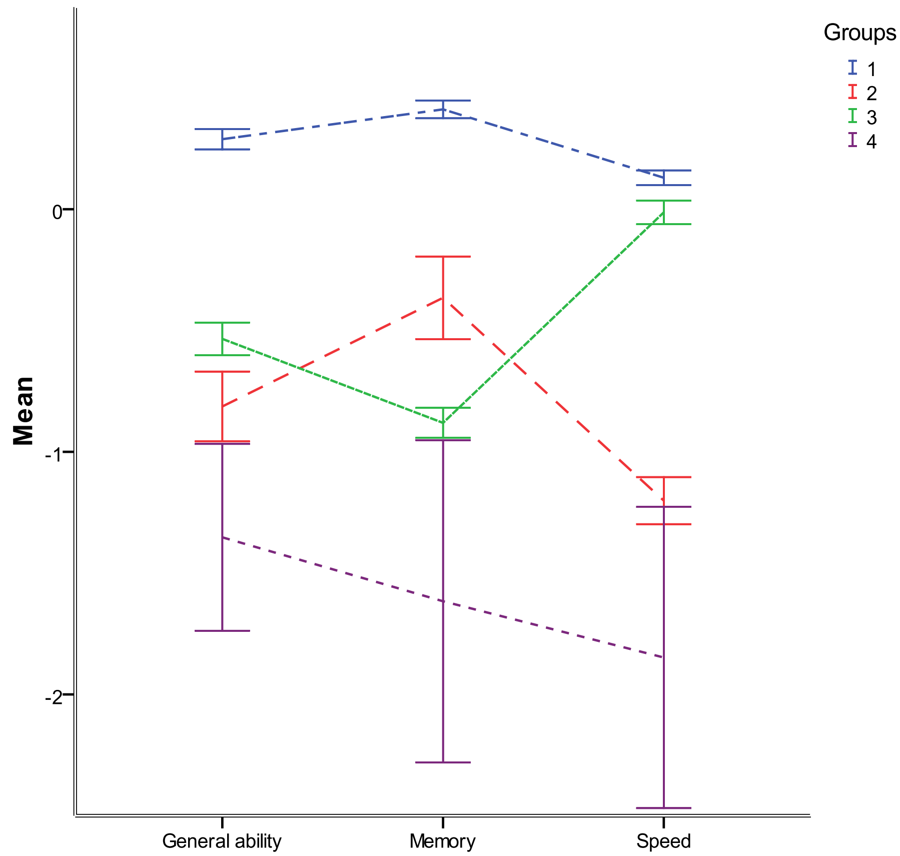


Figure 3.10. The classes' mean scores on each of the cognitive factors, namely *g*, Memory, and Speed for the 4-group solution, with two error bars at 95% confidence interval, as generated from latent class analysis for the Lothian Birth Cohort 1936. Note the similar pattern of scores across the variables between this result and the result derived from CA in Figure 3.7

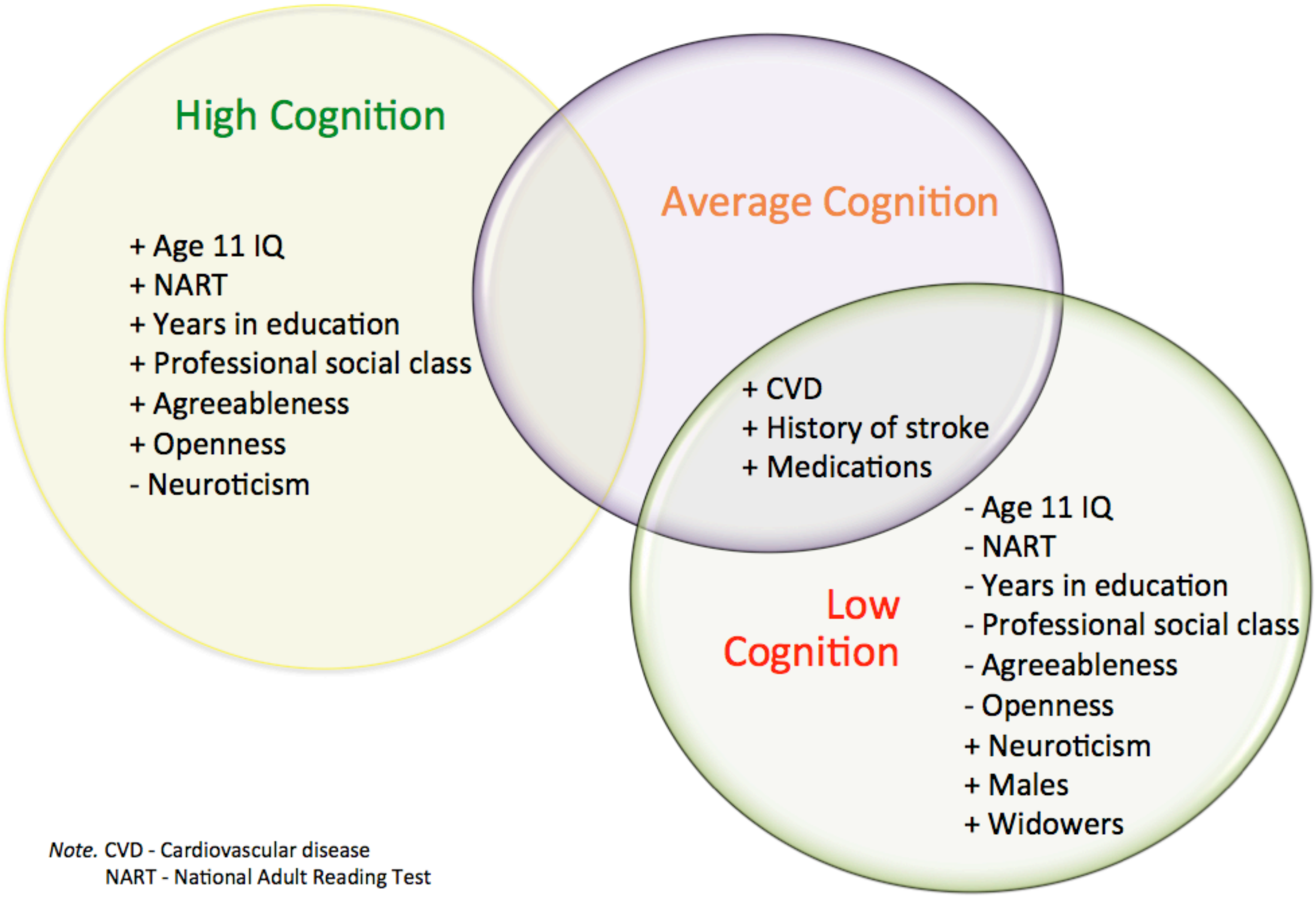


Figure 3.11.Venn diagram displaying common and distinctive significant features characterising the three groups.

4. The Psychosocial Wellbeing Domain

In the previous chapters, I derived three cognitive factors representing major domains of cognitive function from principal components analysis. I then used these to group and classify individuals in the Lothian Birth Cohort 1936 according to their cognitive functioning. In this chapter, I took a similar approach in an attempt to identify and group individuals according to their wellbeing in another major domain representing health in old age: Psychosocial Wellbeing.

Domains of emotional and psychosocial wellbeing being in old age often affect and reflect each other (Charles & Carstensen, 2009; Friedman, Kern & Reynolds, 2010; Gow, Pattie, Whiteman, et al., 2007; Fratiglioni, Paillard-Borg & Winblad, 2004; Hendrie et al., 2006; Okabayashi, Liang, Krause, et al., 2004). They are currently prominent in the ageing literature due to recent re-examinations of the definition of successful aging (e.g. Jeste, Depp & Vahia, 2010; Depp & Jeste, 2009). Researchers have been moving away from solely medical-centred approaches to include more psychosocial perspectives. This is because many older people have some form of functional limitation, physical disability or dependence on others (Bain, Lemmon, Teunisse, et al., 2003). Coping with these issues may reflect good social resources and successful psychosocial adaptation including strategizing and positive attitudes (e.g., Fratiglioni, Wang, Ericsson, Maytan & Winblad, 2000; Okabayashi, Liang, Krause, Akiyama & Sugisawa, 2004; Gow et al., 2004; Friedman, Kern & Reynolds, 2010; Kruger, et al., 2009; Depp, Vahia & Jeste, 2010). Freedom from disease is a priority for successful old age, but autonomy, independence and wellbeing in social and emotional areas of function help in maintaining overall wellbeing and prevent depression (Friedman, Kern & Reynolds, 2010; Depp, et al., 2010; Fratiglioni et al., 2000).

Psychosocial and emotional states of wellbeing also affect cognitive function (Charles & Carstensen, 2009). Physical limitations and poor Quality of Life may trigger feelings of depression, which in old age is manifested differently from adulthood, mainly through cognitive dysfunction, sleep disturbance, anhedonia, and feelings of hopelessness (Fiske, Loebach Wetherell & Gatz, 2009). Although age *per se* is not a risk factor for depression (Baltes & Mayer, 1999), major risk factors include co-morbidity, functional disability, cognitive dysfunction, social isolation, being female, and problems in the neighbourhood (Roberts, Kaplan, Shema, et al., 1997), most of which are more likely to be present in old age. On the other hand, better cognitive skills and higher positive personality traits, such as high scores on Conscientiousness, Extraversion, Openness and Agreeableness, are associated with higher quality physical, social and emotional wellness (Baltes & Frieder, 1997; Gow, Pattie, Whiteman, et al., 2007). Individuals who are involved in more socially active roles and have bigger social networks also tend to have higher cognitive function (Holtzman, Rebok, Saczynski, et al., 2004; Charles & Carstensen, 2009), higher functional ability and lower levels of disease and mortality (Menac, 2003). Thus, active engagement seems to be an integral part of successful wellbeing in old age (Rowe & Khan, 1987). It may also act as a protective factor against stress, depression and consequent pathological effects (Gow, Pattie, Whiteman, et al., 2007), although it is difficult to know if it is cause or effect.

In this chapter my aim was to characterise the ways in which profiles of physical, emotional and psychosocial wellbeing grouped coherently in participants of the LBC1936 at age 70, including levels of Physical Functioning, Quality of Life, and Emotional Wellbeing as the grouping variables. Results from the previous chapter suggested that cognitive functioning in old age lies on a single spectrum ranging from low to high, whereby individuals fall into high, medium, or low functioning groups. Given the interrelatedness among these variables I was interested to explore whether physical, psychosocial and emotional domains of wellbeing relate closely, or whether the domains are independent of each other.

In this chapter I attempted to identify and group individuals according to their psychosocial wellbeing as determined by the variables that have been shown to affect this domain in old age – Physical Function (as opposed to physical fitness, which is more physiologically-based and will be explored in the next chapter), Quality of Life, and Emotional Wellbeing. Therefore I first identified *a priori* some core variables to explore whether there were separable groups with respect to physical, psychosocial and emotional wellbeing. I used latent class analysis (LCA) to extract groups of individuals based on their scores on these components. Finally I investigated whether the groups I identified showed important associations with 'external' variables relating to demographic measures, prior cognitive ability, personality measures, general health measures, disease measures and current cognitive ability.

4.1 Formation of the Psychosocial Components

In this section the formation of the psychosocial components, including Physical Functioning, Quality of Life, and Emotional Wellbeing in the LBC1936 is described. In other chapters of this thesis, areas of cognitive ability and a more physiological basis to physical fitness functioning are studied on a more specific level; however, in this chapter, the study of psychosocial wellbeing in the LBC1936, attempts to cover other vital areas affecting health in old age on a broader level. The selected variables in this chapter also aimed to reflect states when individuals are more susceptible to changes in physical wellbeing, Quality of Life, and Emotional Wellbeing due to age-related changes, accumulation of disease, loss and bereavement.

4.1.1 Physical Function

Variables constituting the physical wellbeing factor included level of physical activity, total number of days active per month, and Townsend's activities of daily living (ADLs). A more thorough description of these variables can be found in Chapter 2, entitled *Methodology*. Table 4.1 shows the raw means and standard deviations (SDs) of all the participants (n = 952) who completed the questions, including scores for females and males separately.

Pearson's correlation coefficients were then computed to test the relationship between these three variables. This is shown in Table 4.2. All markers of physical function correlated significantly with each other at $p < .01$. The correlation coefficients ranged from .26 between level of physical activity and ADLs, to .44 between level of physical activity and number of days active per month, with a mean correlation of .27.

A principal components analysis using maximum likelihood estimation was conducted on the 3 variables measuring Physical Function, using an unrotated solution. The Kaiser-Meyer-Olkin measure of sampling adequacy for the analysis verified the sample adequacy for the analysis, KMO = .528, which is above the acceptable of .5 (Field, 2009). Bartlett's test of sphericity χ^2 (3) = 274.81, $p < .001$, indicated that correlations between subtests were sufficiently large for principal components analysis. An initial analysis was run to obtain eigenvalues for the components in the data. There was only one component and it had eigenvalues over Kaiser's criterion of 1. This explained 52.11% of the total variance. Examination of the scree plot showed inflexions that would also justify retaining 1 component (Figure 4.1). All subtests loaded over .53. This can be seen in Table 4.3. The three variables were analysed for internal consistency estimates using Cronbach's alpha for reliability analysis. The obtained reliability was .79.

4.1.2 Quality of Life

The WHO-QOL (World Health Organisation Quality of Life) questionnaires, which consist of four domains, physical, physiological, social, and environmental, were used to assess Quality of Life (QOL). Table 4.4 shows the raw means and standard deviations (SDs) of all subjects.

Pearson's correlation coefficients were then computed to test the relationship between the four Quality of Life variables. This is shown in Table 4.5. The correlation matrix shows that all domains correlated significantly with each other at $p < .001$. The correlations ranged from .28 between physical and social Quality of Life, to .54 between physical and environmental Quality of Life with a mean correlation of .46.

A principal components analysis was conducted on the four Quality of Life domains using an unrotated solution. The Kaiser-Meyer-Olkin measure of sampling adequacy for the analysis verified the sample adequacy for the analysis, KMO = .740, which is above the acceptable of .5 (Field, 2009). Bartlett's test of sphericity χ^2 (6) = 1064.34, $p < .001$, indicated that correlations between subtests were sufficiently large for principal components analysis. An initial analysis was run to obtain eigenvalues for the components in the data. There was only one component and it had eigenvalues over Kaiser's criterion of 1. This explained 59.95% of the total variance. Examination of the scree plot showed inflexions that would also justify retaining 1 component. This can be seen in Figure 4.2. All subtests loaded over .71, which can be seen in Table 4.6. The subtests that cluster on this component suggest that this represents Quality of Life. The four subtests were analysed for internal consistency estimates using Cronbach's alpha for reliability analysis. The obtained reliability was .75.

4.1.3 Emotional Wellbeing

To measure Emotional Wellbeing, I used the Hospital Anxiety and Depression Scales (HADS), which consist of 2 variables, one for anxiety symptomatology, and the other for depression. Table 4.7 shows the raw means and standard deviations (SDs) of all participants together and separately for males and females.

Pearson's correlation coefficients were computed to test the relationship between the mood variables. The two subtests correlated significantly with each other at $p < .001$ with a correlation of .37. The two subtests were than standardised and their mean was calculated. The scores were re-standardised and reversed so that higher scores represented more positive Emotional Wellbeing.

4.1.4 The Psychosocial Wellbeing components

The three Psychosocial Wellbeing components: Physical Function, Quality of Life, and Emotional Wellbeing that I derived from principal components analysis, were tested for normality using boxplots. Each of the factors showed outliers; however, these were winsorised. Therefore, any score that fell above or below three standard deviations was adjusted to either -3 or +3 standard deviations, depending on whether the outlier was below or above the mean respectively. This process avoided deleting cases that may have highlighted trends of low or high scoring subgroups, but simultaneously avoided extreme outliers that could have influenced the results. All of the variables were restandardised after any adjustments made to them, such as reversal or winsorising. A boxplot with winsorised scores and the reversed mood variable can be seen in Figure 4.3.

Pearson's correlation coefficients were computed for the three psychosocial wellbeing factors. All associations were statistically significant at $p < .001$. The correlations ranged from .20 between Physical Function and Emotional Wellbeing, to .53 between Quality of Life and Emotional Wellbeing. The correlation table can be seen in Table 4.8.

4.2 Formation of groups using latent class analysis

In section 4.1 I derived three broad areas of Psychosocial Wellbeing, representing Physical Function, Quality of Life and Emotional Wellbeing, from principal components analysis. I standardised and analysed these as z-scores (M = 0, SD = 1) throughout the whole study to avoid complications comparing results. The psychosocial factors had already been checked for normality in a previous section

(Section 4.1.4). The aim of extracting these components was to apply them to latent class analysis and attempt to identify subgroups of individuals within the LBC1936 based on their responses to these measures. To identify psychosocial profiles in the LBC1936, I ran a latent class analysis using participants' component scores on Physical Function, Quality of Life, and Emotional Wellbeing.

Two-, three-, four-, five-, and six- class solutions were defined in the latent class models and run on MPlus (Muthen & Muthen, 2005). The results from these solutions were compared using the Akaike information criterion (AIC), the Bayesian information criterion (BIC), and the adjusted BIC. Table 4.9 shows the information criteria values for these models, indicating minimisation of the BIC at five groups. The ENT had a maximum of .825 at 2 groups and a minimum of .653 at 4 groups. The 3- and 6-group solutions had ENTs of .715 and .706, while 5 groups had an ENT of .694. The 2-group solution showed the best discrimination amongst groups, whereas the rest seemed to average at an ENT of .7. The 6-group solution contained groups with less than 5% of the population, and the 4-group solution had the lowest ENT and a lower BIC than the 5-group solution. I selected the 5-group solution for further description and comparisons because it indicated the optimal number of groups by the BIC, and a parsimonious number of subgroups. Participants were assigned to the group to which they had the highest probability of belonging according to their responses on Physical Function, Quality of Life, and Emotional Wellbeing measures as depicted by LCA. For most likely group membership, the probabilities ranged from .71 to .86, indicating reasonably clear group membership for most participants. Table 4.10 illustrates group membership probabilities as they were predicted by LCA.

4.2.1 Profiles of the latent groups

The 5-group solution was selected for further analysis. Table 4.11 shows the means and standard deviations for each group on scores of Physical Function, Quality of Life, and Emotional Wellbeing. I labelled the group comprising the majority of the sample (n = 515, 47.2%) High Wellbeing as they tended to score relatively highly across all three components. I also labelled groups representing Average Wellbeing (n = 417, 38.3%) and Poor Wellbeing (n = 37, 3.4%), reflecting generally those overall levels of function. There were contrasting patterns of wellbeing across components in the two final groups: one group was physically fit but had relatively low emotional wellbeing (n = 60, 5.5%), which I labelled High Function/Low Spirits; another was in relatively poor physical condition but showed relatively high emotional wellbeing (n = 62, 5.7%), which I labelled Low Function/High Spirits. The groups' means on each of the psychosocial components are illustrated in Figure 4.4.

Like the cognitive latent class profiles before it, the psychosocial class solutions also seem to have suggested a continuous pattern of wellbeing across groups, with important exceptions in two groups, i.e. the reversed pattern between Physical Function and Emotional Wellbeing in the Low Function/ High Spirits and the High Function/Low Spirits groups worth exploring further. In the next section, a number of variables that may distinguish amongst the groups were identified and used as descriptors and predictors of the 5 groups.

4.3 Descriptors and predictors of Psychosocial Wellbeing at age 70

In the previous section I applied LCA to the LBC1936, with the aim of generating classes of 70 year-old individuals according to their Physical Function, Emotional Wellbeing, and Quality of Life. Results supported a 5-group solution consisting of poor, average, good wellbeing and two groups with mixed results. The majority of cases fell into the Average (n = 417, 38.3%) and High Wellbeing (n = 515, 47.2%) groups; however, a substantial number of cases showed unsatisfactory levels of wellbeing.

The aim of this section was to learn how the 5 groups differed on variables relating to demographic measures, personality, health, physical status, presence of disease, cognitive functioning, and medication use and medical conditions. These variables were chosen to provide descriptive data and help in creating a profile for the 5 groups, and to find out how they distinguished amongst them. These variables were referred to as descriptors and predictors of Psychosocial Wellbeing at age 70. A thorough description of all the variables mentioned in this chapter can be found in Chapter 2, entitled *Methodology*. In all instances, analyses of variance (ANOVA) were first used to find out if significant differences were present amongst the classes on any of the variables. Post-hoc analysis for the significant findings from ANOVA using Tukey's Honestly Significant Difference (HSD) test comparisons was also administered in order to find out which classes differed significantly from each other. Tukey's HSD test is a multiple-comparison statistical test used to discover which classes differ significantly from each other by comparing all pairs of means. This was followed by multinomial logistic regression with the aim of predicting group membership for each of the variables that were being analysed. The Low Wellbeing group was used as the baseline group in all multinomial logistic regression analyses run in this chapter. The logistic regression *p*-values were also adjusted for multiple testing using the Bonferroni correction in all regression analyses in this chapter. The external variables were chosen to provide descriptive data of the 5 groups and to explore how they distinguished amongst them. The main aim of this was to summarise how differences in Psychosocial Wellbeing in old age may relate to other outcome variables.

4.3.1 Demographic measures and prior cognitive ability

Demographic measures, such as number of years in full-time education, social class, marital status, and valuable information such as age-11 IQ are basic yet important determinants that may distinguish amongst individuals' level of wellbeing. Literature shows that individuals who are married and have big social networks have better Quality of Life, report less depression, and display less physical impairment than individuals who are alone (Antonucci, Lansford & Akiyama, 2001; Bowling, Edelmann, Leaver & Hoekel, 1989).

In this study, the demographic measures and prior cognitive ability measures used to explore differences amongst the groups included sex, age-11 IQ, the National Adult Reading Test (NART), number of years in formal education, marital status, living status, and social class. Tables 4.12 and 4.13 show the raw means and standard deviations along with the mean differences of the continuous and categorical demographic variables for the 5 groups. Significant differences amongst the groups were found for age-11 IQ, the NART, social class, and marital status.

The High Wellbeing group had the highest mean number of years of formal education; however, post-hoc analysis showed that this did not differ significantly from the rest of the groups. The majority of individuals (73.0%) in the High Wellbeing group were also still married, as opposed to being widowed, separated or divorced; significant differences ($p < .05$) were present between the High Wellbeing group and the Low Wellbeing group (only 51.4% were still married in this group). The Low Wellbeing group had a higher percentage of divorce than the rest of the groups, showing a significant difference from the High Wellbeing group (13.5% vs. 6.8%). A significantly higher number of individuals in the High Wellbeing group belonged to the professional social class showing a significant difference from the Low Function/High Spirits group (20.6% vs. 6.0%). There were no significant differences among the other groups.

On post-hoc testing the High Wellbeing group had significantly higher age-11 IQ and higher NART scores than the rest of the groups. SDs of this group's scores were used as the base for calculating effect sizes. Significant differences for age-11 IQ were present between the High Wellbeing group and the High Function/Low Spirits group (Cohen's $d = 0.45$) and the Low Function/High Spirits group ($d = 0.35$). Significant differences in NART scores were also present between the High Wellbeing group and the High Function/Low Spirits group ($d = 0.36$). No other significant differences were found amongst the groups. This can be seen in Table 4.14.

Results from the multinomial logistic regressions showed that for every unit increase in age-11 IQ, the odds of being in the High Wellbeing group rather than the Low Wellbeing group were 1.02 times as great. For every extra year in education, the odds of being in the Low Function/High Spirits, Average Wellbeing, High Wellbeing, and High Function/Low Spirits groups rather than the Low Wellbeing group were 1.56, 1.52, 1.41, and 1.45 respectively. Furthermore, the odds of not being married were lower for the Low Function/High Spirits (OR = 0.79), Average Wellbeing (OR = 0.82), High Wellbeing (OR = 0.71), and High Function/Low Spirits (0.72) groups, rather than the Low Wellbeing group. The odds of living alone, were lower for the Low Function/High Spirits group then for the Low Wellbeing group, OR = 0.54. Finally, the Low Function/High Spirits (OR = 1.58) and the Average Wellbeing (OR = 1.38) groups were more likely to belong to a lower social class than the Low Wellbeing group. The NART did not show any significant results. Table 4.15 shows the results.

4.3.2 Personality measures

The relationship between wellbeing and personality is widely studied (e.g. Roberts, Kuncel, Shiner, Caspi & Goldberg, 2007; Caspi et al., 2005; Friedman, Kern & Reynolds, 2010). Individuals with higher scores on Neuroticism are more likely to experience poor physical health and report poor wellbeing (Friedman, Kern & Reynolds, 2010). Extraversion, on the other hand, is linked to positive social interaction and an active lifestyle. Freidman, Kern and Reynolds (2010) found that the strongest predictor of good health in men is a high score on the Agreeableness trait, whereas in women, it is low scores on Neuroticism. High Conscientiousness in females is also associated with better physical health, and better social and subjective wellbeing (Freidman, Kern & Reynolds, 2010).

Groups' personality means in this study were compared using the NEO-PI-R inventory, i.e. traits of Neuroticism, Extraversion, Openness, Conscientiousness, and Agreeableness. Results depicting the raw scores, standard deviations, and differences amongst the groups can be seen in Table 4.16 and post-hoc tests in Table 4.17. Significant differences amongst the groups were found for Neuroticism, Openness, Agreeableness, and Conscientiousness. The direction of results is described in more detail below.

For Neuroticism, the mean scores of the groups—from high to low—were ordered as Low Wellbeing, High Function/Low Spirits, Low Function/High Spirits, Average Wellbeing, and High Wellbeing, with significant differences separating these groups. The effect size (*d*) of the difference between the lowest and highest-scoring group was 2.38, a large effect (Cohen, 1988). For Extraversion, the mean scores of the groups—from high to low—were ordered as High Wellbeing, Average Wellbeing, High Function/Low Spirits, Low Function/High Spirits, and Low Wellbeing, with significant differences separating these groups. The effect size (*d*) of the difference between the lowest and highest-scoring group was 1.45. For Agreeableness, the mean scores of the groups—from high to low—were ordered as High Wellbeing, Average Wellbeing, High Function/Low Spirits, Low Function/High Spirits, and Low Wellbeing, with significant differences separating these groups. The effect size (*d*) of the difference between the lowest and highest-scoring groups was 0.93. For Conscientiousness, the mean scores of the groups—from high to low—were ordered as High Wellbeing, Average Wellbeing, Low Wellbeing, High Function/Low Spirits, Low Function/High Spirits, with significant differences separating the groups. The effect size (*d*) of the difference between the lowest and the highest-scoring groups was 1.14.

The High Wellbeing group was the only one that tended to score consistently highly on a range of favourable personality traits such as Conscientiousness, Agreeableness and Extraversion; whereas the Low Wellbeing group tended to show an opposite pattern, specifically scoring highly on Neuroticism, and low on Agreeableness and Extraversion. No significant differences among the groups were present on the Openness trait.

Results (Table 4.18) from the multinomial logistic regressions showed that for every unit increase in Neuroticism, the odds of belonging to the Low Function/High Spirits group, the Average Wellbeing and the High Wellbeing groups were lower than belonging to the Low Wellbeing group (OR = 0.88, 0.84, and.0.72, respectively). On the other hand, for every unit increase in Extraversion, the odds of belonging to the Low Function/High Spirits group rather than the Low Wellbeing were 1.08, and the analogous odds of belonging to the Average Wellbeing, the High Wellbeing and the High Function/Low Spirits groups were 1.11; 1.17; and 1.10. For every unit increase in Agreeableness, the odds of being in the Average Wellbeing group rather than the Low Wellbeing were 1.07, the odds of being in the High Wellbeing group were 1.06, and the odds of being in the High Function/Low Spirits group were 1.06. Lastly, for every unit increase in Conscientiousness the odds of being in the Low Function/High Spirits group rather than the Low Wellbeing group were 0.88, and the odds of being in the High Function/Low spirits were 0.94. In summary, individuals in the Low Wellbeing group were more likely to have high traits of Neuroticism and low traits of Extraversion than individuals in the other groups. They were also less likely have high scores on Agreeableness than individuals in the Average Wellbeing, the High Wellbeing, and the High Function/Low Spirits groups but were likely to have higher Conscientious scores than individuals in the Low Function/High Spirits and the High Function/Low Spirits groups.

4.3.3 Health measures

There exist negative correlations between smoking prevalence, weight problems and wellbeing (McCann, 2010; Yan, Daviglus, Liu, Pirzada, Garside, Schiffer et al., 2004) and a positive association between moderate intake of alcohol and wellbeing (Lang, Wallace, Huppert & Melzer; 2007; Corley, Xueli, Brett, Gow, Starr, Kyle, et al., 2011).

In this study variables relating to health, including body mass index (BMI), units of alcohol consumed per week, smoking status, and the presence/absence of the APOE e4 were used to explore differences amongst the 5 groups. Tables 4.19, 4.20 and 4.21 show the results. The Low Function/High Spirits group had a higher percentage of smokers (27.4%) than the rest of the groups. This differed significantly ($p < .01$) from the Average Wellbeing (12.5%) and the High Wellbeing (11.9%) groups. No significant differences in BMI, total units of alcohol per week, or APOE e4 allele status were found among the groups.

Results from the multinomial logistic regression analysis showed that for every unit increase in BMI, the odds of being in the Average Wellbeing, High Wellbeing and High Function/Low Spirits groups were lower rather than the Low Wellbeing group (ORs = 0.94, 0.93, and 0.94, respectively). For every unit increase in alcohol intake per week, the odds of being in the Low Function/High Spirits group rather then the Low Wellbeing group were 1.09, the odds of being in the Average Wellbeing group were 1.11, and the odds of being in the High Function/Low Spirits group were 1.09. Finally, the odds of being a current or an ex-smoker were lower for participants in the Low Function/High Spirits group, the High Wellbeing group and the High Function/Low Spirits group than the Low Wellbeing group (ORs = 0.51, 0.49, and 0.65). In summary, individuals in the Low Wellbeing group were more likely to have a higher BMI than individuals in the Average Wellbeing, High Wellbeing, or High Function/Low Spirits groups; individuals in the Low Wellbeing group were also more likely to drink higher units of alcohol per week, and less likely to have never smoked. Table 4.22 shows the results.

4.3.4 Physical fitness measures

Physical measures of health such as grip strength, lung function and walk-time are a reflection of physical fitness and health. Associations exist between these variables and cognitive function (Baltes & Lindenberger, 1994). Four measures of physical strength were used to explore differences amongst the groups; these included grip strength, 6-metre walk time, forced expiratory volume in 1 second (FEV_1), and forced vital capacity (FVC).

Results (in Tables 4.23 and 4.24) showed significant differences amongst groups for walk time, FEV_1 and FVC. The High Wellbeing and Average Wellbeing groups had significantly faster average six-meter walk-time than the Low Wellbeing group (d = .99), and the Low Function/High Spirits group (d = .91). The High Wellbeing group also had significantly better FEV_1 (SD = 1) than the Low Wellbeing group ($p < .05$, $d = 0.58$) and the Low Function/High Spirits group ($p < .001$, $d = .63$); the High Wellbeing group also had a better FCV (SD = 1) than the Low Function/High Spirits group ($p < .001$, d = .67). The Average Wellbeing group had significantly better FEV_1 (SD = 1) and FVC (SD = 1) than the Low Function/ High Spirits group ($p < .05$, $d = 0.53$; $p < .001$, d = 0.65). No other group differences were significant.

Results from the multinomial logistic regression showed that for every unit increase in grip strength the odds of being in the Low Function/High Spirits groups rather than the Low Wellbeing group were 1.51 times greater, and the odds of being in the High Wellbeing group rather than the Low Wellbeing group were 1.37 times greater. For every second faster in the 6-metre walk time, the odds of being in the Low Function/High Spirits group rather than the Low Wellbeing group were 1.01 times as great. Analogously, the odds of being of being in the Average Wellbeing and the High Function/Low Spirits group rather than the Low Wellbeing group were 2.03 and 1.38 times as great. For every unit increase in FEV_1 the odds of being in the High Function/Low Spirits group rather than the Low Wellbeing group were 1.96 times as great, and similarly for every unit increase in FVC the odds of being in High Function/Low Spirit group rather than the Low Wellbeing group were 0.44. Table 4.25 shows the results.

2.3.5 Disease status

Variables used to explore differences amongst groups on disease-related variables were, presence/absence of high blood pressure, diagnosis of diabetes, history of cardiovascular disease, blood circulation problems, and history of stroke. Tables 4.26 and 4.27 show the results.

The Low Function/High Spirits group had the highest percentage (56.5%) of individuals with high blood pressure. This differed significantly ($p < .05$) from the High Wellbeing group (36.4%) and the High Function/Low Spirits group (28.3%). The highest percentage of individuals with diabetes was found in the Low Wellbeing Group (35.1%), which significantly differed ($p < .001$) from the Average Wellbeing group (8.2%), the High Wellbeing group (5.3%), and the High Function/Low spirits group (6.7%). The Low Function/High Spirits group also had a high percentage of individuals with diabetes (21%), showing significant differences from the Average Wellbeing group ($p < .01$), the High Wellbeing group (at $p < .001$, $d = .48$), and the High Function/Low Spirits group (at $p < .05$). Individuals in the Low Wellbeing group also had the highest percentage (51.4%) of history of CVD, showing significant differences from the Average Wellbeing (23.8%, $p < .01$) and the High Wellbeing group (21%, $p < .001$). Significant differences ($p < .05$) were also present between the High Wellbeing group and the Low Function/High Spirits group. There were no significant differences among the groups in history of stroke.

Results from the multinomial logistic regressions showed that individuals in the Low Function/High Spirits, the Average Wellbeing, the High Wellbeing, and the High Function/Low Spirits groups were less likely to be diagnosed with Diabetes than the Low Wellbeing group (ORs = 0.46, 0.18, 0.13; and 0.16 respectively). Likewise, individuals in the Low Function/High Spirits, the Average Wellbeing, the High Wellbeing, and the High Function/Low Spirits groups were less likely to have CVD than the Low Wellbeing group (ORs = 0.53, 0.31, 0.29, and 0.51, respectively). Furthermore, individuals in the High Function/Low Spirits group were less likely to have high blood pressure (OR = 0.51). Individuals with blood circulation problems were more likely to belong to the Low Wellbeing group rather than the Average Wellbeing group (OR = 0.57), the High Wellbeing (OR = 0.52), or the High Function/Low Spirits group (OR = 0.45). Lastly, the odds of being in the High Wellbeing group rather than the Low Wellbeing group were 0.40 times greater for individuals who have suffered stroke. Table 4.28 shows the results.

4.3.6 Cognitive measures

In this study, three variables relating to cognitive ability, namely General Cognitive Ability (*g*), Memory, and Speed, were used to explore differences amongst the 5 groups. These variables have already been used to analyse the LBC1936's cognitive ability at age 70 in Chapter 3. Results showed significant differences amongst groups for *g* and Speed. Tables 4.29 and 4.30 show the results from the ANOVAs and the post-hoc tests.

There were significant mean differences among the groups in *g*, suggesting that higher *g* in old age was related to better mental and physical health. The High Wellbeing group had significantly higher scores on *g* than the rest of the groups. The mean scores of the groups were ordered as High Wellbeing, Average Wellbeing, High Function/Low Spirits, Low Function/High Spirits, and Low Wellbeing with significant differences separating these groups. The effect size (*d*) of the difference between the lowest and highest-scoring groups was .96.

Speed also showed significant differences among the Low Wellbeing and the High Wellbeing groups ($p < .05$, $d = .39$); and the Low Function/High Spirits and High Function/Low Spirits groups ($p < .05$, $d = .60$); with individuals with faster reaction time (those in the High Wellbeing and the High Function/Low Spirits groups) associated with better physical and psychosocial health.

Results from the multinomial logistic regressions showed that for every unit increase in *g* the odds of belonging to the Average Wellbeing group rather than the Low Wellbeing group were 1.60 times as great. The analogous odds ratio for belonging to the High Wellbeing was 1.91 times as great. Table 4.31 shows the results.

4.3.7 Medication and medical conditions

Individuals with more medical conditions are more likely to be depressed, have a lower quality of life and are less likely to be physically active due to disability. In this study I also looked at a number of medical conditions, and total number of drugs taken, in order to find out if any differences exist amongst groups in relation to existence of medical conditions and/or drugs. Two variables, number of existing medical conditions, and total number of drugs taken, were used in this set of analyses. Tables 4.32 and 4.33 show the descriptive and post-hoc results.

Significant differences among groups were present on total number of medications taken and number of diagnosed medical conditions. The means of the groups were ordered as Low Wellbeing, Low Function/High Spirits, High Function/Low Spirits, Average Wellbeing, and High Wellbeing, with significant differences separating these groups. The effect size (*d*) of the difference between the groups with the lowest and highest number of medications was 1.20. The Low Wellbeing and the Low Function/High Spirits groups also had the highest number of medical conditions (mean = 5.17 and 4.42 respectively, SD = 2.76). The groups were ordered as Low Wellbeing, Low Function/High Spirits, Average Wellbeing, High Function/Low Spirits, and High Wellbeing with significant differences amongst the groups. The effect size (*d*) of the difference between the groups with the lowest and highest number of medical conditions was 1.53.

Results from the multinomial regressions showed that with every unit increase in drugs taken, it was more likely to belong to the Low Wellbeing group than the Average

Wellbeing group (OR = 0.80) or the High Wellbeing group (OR = 0.81). Similarly, with every increase in medical conditions it was more likely of belonging to the Low Wellbeing than the Average Wellbeing, the High Wellbeing or the High Function/Low Spirits groups (ORs = 0.69, 0.54, and 0.56). This illustrates that individuals in the Low Wellbeing group were more likely to have more medical conditions and as a consequence be on more medication. Table 4.34 shows the results.

A Venn diagram illustrating the similarities and differences amongst the groups can be seen in Figure 4.5.

4.4 Summary of results

The primary aim of this study was to identify patterns of Psychosocial Wellbeing amongst 70-year old individuals. Measures representing this domain - Physical Function, Quality of Life, and Emotional Wellbeing were entered into latent class analysis to reveal these patterns. A 5-group solution was selected. Although results indicated that wellbeing across these domains was primarily uni-dimensional (i.e. ranging from low to high wellbeing), they also showed evidence for the presence of groups. Consistent with the literature on young-old age (Gerstrof, et al., 2006; Ko et al., 2007), the largest group scored relatively highly in the physical, psychosocial, and emotional domains of wellbeing, indicating that the majority of participants were doing reasonably well. Despite this, results also indicated that some individuals in this sample seemed to be in relatively good physical condition but still to experience emotional stress, and some individuals appeared to be in relatively poor physical condition, yet were relatively satisfied with their situations. These disparities were consistent with some previous studies that also have focused on such differences (Smith & Baltes, 1997; Gerstorf, et al., 2006; Ko et al., 2007), emphasising that the associations among physical function, emotional stability and quality of life typically depicted in the literature (e.g. Rennemark, Lindwall, Halling & Berglund, 2009; Strawbridge, Deleger, Roberts & George, 2002) are never complete.

External variables relating to demographic, personality, health and health behaviour measures were used to generate profiles and assess differences amongst the groups. The High Wellbeing group had the most favourable characteristics – individuals in this group had good physical function, a high quality of life, and high emotional wellbeing. The High Wellbeing group had significantly higher scores on *g*, a higher age-11 IQ, higher NART scores, and more years in formal education than the rest of the groups. The majority of individuals in this group were still married, as opposed to being widowed, separated or divorced. The High Wellbeing group was also the healthiest group – most individuals had never smoked, and had the highest forced expiatory volume in 1 second and highest forced vital capacity. It also had the lowest percentage of people with medical conditions and/or on medication of all the groups. The Low Wellbeing group on the other hand, had the least favourable characteristics. It could easily be described as the exact opposite of the High Wellbeing group. High scores on Neuroticism, a high body mass index, a history of cardiovascular disease, and presence of diabetes were predictors of the Low Wellbeing group. This group also had the highest percentage of individuals who suffered stroke.

Results indicated personality traits as strong discriminators among the profiles. The separable groups differed considerably (effect sizes ranging from 0.45 to 2.16) in Neuroticism scores. Personality shows considerable life-long stability and current levels are associated with late-life wellbeing and mortality (Deary, Batty, Pattie & Gale, 2008; Deary, Weiss & Batty, 2010; Roberts & DelVecchio, 2000; Weiss, Gale, Batty & Deary, 2009; Wilson, Kruger, Gu et al., 2005). In fact, the groups that had higher Neuroticism scores, specifically the High Function/Low Spirits group and the Low Wellbeing group, also had more diagnosed medical conditions and were taking more medications than the High Wellbeing group. Although the literature indicates that, overall, individuals with high physical functioning generally tend to score low in Neuroticism and have relatively high spirits (Gale, Aihie Sayer, Cooper et al., 2011), this overall observation may conceal underlying subgroups with different characteristics.

In this study there was an interesting contrast in the level of Emotional Wellbeing among participants with most likely membership in the Low Function/High Spirits and the High Function/Low Spirits groups. The Low Function/High Spirits group had the lowest scores on Conscientiousness (effect sizes up to 1.14), which was reflected in their behaviour: this group contained the highest percentage of current smokers and had low mean physical function. This group also had the lowest levels of FEV_1 and FVC, with effect sizes ranging from 0.53 to 0.67 with respect to the other groups. This was not surprising given their smoking and physical function status. It seemed that this group was one of the least healthy, but still had relatively high spirits. The High Function/Low Spirits group had significantly higher levels of Neuroticism ($d = .84$) and significantly lower levels of Extraversion than the Low Function/High Spirits group ($d = .65$), a result that reflected the well-known association between Neuroticism and depression (Gale et al., 2011). This may have reflected environmental surroundings, social ties, and levels of perceived support. For example, there is evidence that individuals with physical disability but with supportive environments who are resilient, tolerant of negative change, and have positive attitudes are less likely to feel depressed than physically fit individuals who do not have these characteristics (Depp, Vahia & Jeste, 2010; Lamond et al., 2008).

4.5 Final conclusions

The primary aim of this study was to identify profiles of Psychosocial Wellbeing among 70-year old individuals. Measures representing Psychosocial Wellbeing included Physical Function, Quality of Life, and Emotional Wellbeing. These factors were entered into a latent class analysis (LCA), and 5 groups of individuals were revealed. External variables representing measures of demography, prior cognitive ability, personality, general health, physical health, disease status, cognitive function, and medical conditions and medications taken, were used to describe and explore differences amongst the 5 groups that had been generated.

Results suggested that wellbeing in the LBC1936 at age 70 was primarily uni-dimensional but also showed evidence of groups of individuals with uneven patterns, showing strong associations with various personality traits. This indicated that wellbeing in this age group is not necessarily an all-or-nothing phenomenon, but rather individuals can show relatively successful patterns in one area despite relatively poor functioning in other areas. This supports previous research findings (Ko et al., 2007; Smith & Baltes, 1997) demonstrating uneven profiles of function within individuals.

Table 4.1
Means of physical well being for total participants, males and females (SDs in parentheses)

Physical well being	Total participants n = 952	Males n = 470	Females n = 482
Level of physical activity	2.98 (1.11)	3.08 (1.09)	2.88 (1.12)
Number of days active per month	7.68 (8.12)	8.00 (8.11)	7.36 (8.13)
ADLs (reversed)	.99 (1.95)	.72 (1.57)	1.27 (2.24)

Note. ADLs = Activities of daily living; this variable was reversed so that a higher score equated to better functioning.

Table 4.2
Correlation coefficients of Physical Function

		1	2	3
1.	Level of physical activity	-		
2.	Number of days active per month	.44**	-	
3.	ADLs (reversed)	.26**	.11**	-

Note. ADLs = Activities of Daily Living. ** Correlation is significant at $p < .01$ (Pearson's r, 2 tailed), no adjustment for multiple testing.

Table 4.3

Component loadings for the first unrotated principal component of the three variables reflecting Physical Function

Variables	Loadings
Level of physical activity	.84
Days active per month	.76
ADLs	.53

Note. ADLs = activities of daily living.

Table 4.4

Means of Quality of Life (QOL) domains for total participants, males and females (SDs in parentheses)

Quality of Life domains	Total participants n = 959	Males n = 472	Females n = 487
Physical	16.10 (2.64)	16.11 (2.64)	16.10 (2.64)
Psychological	15.67 (1.81)	15.80 (1.82)	15.54 (1.78)
Social	17.14 (2.39)	16.96 (2.38)	17.32 (2.40)
Environmental	16.71 (1.84)	16.72 (1.86)	16.71 (1.82)

Note. The scales lie on a range from 0 to 20 with 20 being the highest score possible. A higher score means a better QOL in the respective domain.

Table 4.5

Correlation coefficients for the Quality of Life variables

		1	2	3	4
1.	Physical QOL	-			
2.	Psychological QOL	.53***	-		
3.	Social QOL	.28***	.53***	-	
4.	Environmental QOL	.47***	.54***	.43***	-

Note. QOL = Quality of Life. *** Correlation is significant at $p < .001$, (Pearson's r, 2 tailed) without adjustment for multiple testing.

Table 4.6

Component loadings for the first unrotated principal component of the four variables reflecting Quality of Life.

Variables	Loadings
Physical QOL	.85
Psychological QOL	.80
Social QOL	.73
Environmental QOL	.71

Note. QOL = Quality of Life.

Table 4.7

Means of Emotional Wellbeing for total subjects, males and females (SDs in parentheses)

Emotional Wellbeing	Total subjects n = 1086	Males n = 546	Females n = 540
Anxiety	4.89 (3.18)	4.20 (2.88)	5.57 (3.32)
Depression	2.80 (2.22)	2.88 (2.30)	2.71 (2.15)

Table 4.8.

Correlation coefficients for the psychosocial components.

		1	2	3
1.	Physical Function	-		
2.	QOL	.300**	-	
3.	Emotional Wellbeing	.203**	.572**	-

Note. QOL = Quality of Life ** Correlation significant at $p < .01$ (Pearson's r 2-tailed), with no adjustment for multiple testing.

Table 4.9

Model information criteria for each of the, two-, three-, four-, five- and six- group solutions.

Group-solution	AIC	BIC	Adjusted BIC
Two	8106.02	8155.96	8124.20
Three	8003.64	8073.56	8029.09
Four	7949.01	8038.90	7981.73
Five	7917.12	8026.98	7957.10
Six	7915.95	8045.79	7963.21

Note. AIC = Akaike information criterion. BIC = Bayesian information criterion.

Adjusted BIC = (n* = (n* = (n + 2) / 24).

Table 4.10

Probability of falling into a latent group by psychosocial measures in the Lothian Birth Cohort 1936

Class	N	Probability of group 1	Probability of group 2	Probability of group 3	Probability of group 4	Probability of group 5	Total
1	37	.04	.86	.00	.00	.10	100%
2	62	.71	.01	.22	.01	.05	100%
3	417	.08	.00	.75	.15	.03	100%
4	514	.00	.00	.15	.85	.00	100%
5	60	.08	.11	.09	.00	.72	100%

Table 4.11

Means of psychosocial measures (standard deviations in parentheses) for each of the latent groups of the Lothian Birth Cohort 1936.

Class	N (%)	Physical Function	Quality of Life	Emotional Wellbeing
Low Wellbeing	37 (3.4)	-1.41 (.85)	-2.48 (.59)	-2.41 (.52)
Low Function/High Spirits	62 (5.7)	-1.37 (.84)	-1.44 (.62)	-.65 (.52)
Average Wellbeing	417 (38.3)	.12 (.89)	-.15 (.65)	-.39 (.46)
High Wellbeing	515 (47.2)	.17 (.89)	.59 (.68)	.80 (.43)
High Function/Low Spirits	60 (5.5)	.14 (1.00)	-.88 (.72)	-1.98 (.44)
df		4	4	4
F		61.90	302.62	1051.38
p		.001	.001	.001

Table 4.12

Raw means, standard deviations (SDs) and significance values of age-11 IQ, NART, and number of years in formal education for each of the 5 groups in the Lothian Birth Cohort 1936.

Variables	Group 1		Group 2		Group 3		Group 4		Group 5			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	df	F
Age 11 IQ	97.7	17.4	95.2	17.6	99.5	14.5	101.9	13.9	93.0	18.6	4	7.1
NART	34.1	7.2	32.6	9.0	34.1	8.3	35.3	7.8	32.1	9.3	4	3.5
Education (years)	10.4	.9	10.6	1.0	10.7	1.2	10.8	1.1	10.5	1.2	4	2.6

Note. NART = National Adult Reading Test. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits.

Table 4.13

Proportions, percentages and significance values of differences in sex, marital status, living status, and social class status for each of the 5 groups in the Lothian Birth Cohort 1936

Variables	1		2		3		4		5				
	n	%	n	%	n	%	n	%	n	%	df	X^2	*p*
Sex													
Male	16	48.5	28	45.2	196	47.1	280	54.5	27	45.0			
Female	21	56.8	34	54.8	220	52.9	233	45.5	33	55.0			
N	37	100	62	100	416	100	514	100	60	100	1	0.23	.880
Marital status													
Married	19	51.4	39	62.9	298	71.6	375	73	42	70			
Single	2	5.4	3	4.8	24	5.8	33	6.4	3	5.0			
Divorced	5	13.5	8	12.9	28	6.7	35	6.8	8	13.3			
Co-habiting	2	5.4	0	0	4	1.0	11	2.1	0	0			
Widowed	9	24.3	12	19.4	60	14.4	58	11.3	7	11.7			
Other	0	0	0	0	0	0	1	.2	0	0			
N	37	100	62	100	414	100	517	100	61	100	5	2397.0	.001

Table 4.13 (cont).

Variables	1		2		3		4		5				
	n	%	n	%	n	%	n	%	n	%	df	X^2	*p*
Living status													
Alone	12	32.4	22	35.5	88	21.2	126	24.5	18	30			
Not alone	25	67.6	40	64.5	328	78.8	388	75.5	42	70			
N	37	100	62	100	416	100	514	100	60	100	1	284.9	.001
Social class													
I	6	17.1	8	13.3	63	15.3	104	20.6	9	15.8			
II	14	40.0	17	28.3	155	37.7	194	38.4	20	35.1			
III (non-manual)	5	14.3	14	23.3	101	24.6	115	22.8	11	19.3			
III (manual)	7	20.0	17	28.3	74	18.0	76	15.0	14	24.6			
IV	2	5.7	3	5.0	15	3.6	16	3.2	2	3.5			
V	1	2.9	1	1.7	3	.7	0	0	1	1.8			
N	37	100	60	100	411	100	505	100	57	100	5	580.5	.001

Note. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits.

Table 4.14

Tukey's HSD post-hoc results for age-11 IQ and NART, years in education, social class and marital status.

Effect	Compare	Effect size Cohen's *d*	Mean difference	95% Confidence Interval Lower	Higher
Age 11 IQ	1-2	0.03	2.56	-6.11	11.22
	1-3	0.23	-1.74	-8.99	5.50
	1-4	0.37	-4.13	-11.31	3.05
	1-5	0.14	4.82	-3.92	13.57
	2-3	0.26	-4.30	-9.88	1.40
	2-4	0.35	-6.68*	-12.19	-1.19
	2-5	0.10	2.27	-5.15	9.70
	3-4	0.10	-2.38	-5.15	.38
	3-5	0.36	6.57	.87	12.28
	4-5	0.45	8.96***	3.33	14.58
NART	1-2	0.12	1.53	-3.08	6.14
	1-3	0.08	-.27	-3.84	3.78
	1-4	0.24	-1.17	-4.95	2.61
	1-5	0.16	1.38	-2.66	6.61
	2-3	0.18	-1.55	-4.58	1.47
	2-4	0.33	-2.70	-5.68	.29
	2-5	0.03	.35	-3.57	4.47
	3-4	0.15	-1.14	-2.61	.32
	3-5	0.22	2.00	-1.06	5.07
	4-5	0.36	3.14*	.11	6.17

Table 4.14 (cont.)

Effect	Compare	Effect size Cohen's *d*	Mean difference	95% Confidence Interval	
				Higher	Lower
Years in Education	1-2	0.33	-.22	-.99	.34
	1-3	0.40	-.35	-.97	.14
	1-4	0.52	-.45	-1.07	.03
	1-5	0.20	-.11	-.87	.46
	2-3	0.09	-.13	-.51	.33
	2-4	0.19	-.23	-.61	.22
	2-5	0.09	.11	-.43	.68
	3-4	0.09	-.10	-.31	.10
	3-5	0.17	.25	-.21	.63
	4-5	0.26	.34	-.10	.73
Social class	1-2	0.18	-.20	-.73	.33
	1-3	0.26	.01	-.42	.45
	1-4	0.41	.16	-.27	.60
	1-5	0.45	-.05	-.59	.48
	2-3	0.04	.22	-.12	.56
	2-4	0.18	.36*	.03	.70
	2-5	0.23	.14	-.31	.61
	3-4	0.17	.15	-.02	.31
	3-5	0.22	-.0 7	-.42	.28
	4-5	0.06	-.22	-.56	.13

Table 4.14 (cont.)

Effect	Compare	Effect size Cohen's *d*	Mean difference	95% Confidence Interval	
				Higher	Lower
Marital Status	1-2	0.29	.38	-.43	1.19
	1-3	0.06	.66	-.01	1.32
	1-4	0.07	.73*	.07	1.39
	1-5	0.10	.68	-.14	1.49
	2-3	0.35	.28	-.25	.81
	2-4	0.21	.35	-.17	.88
	2-5	0.39	.30	-.41	1.00
	3-4	0.14	.08	-.18	.33
	3-5	0.04	.02	-.52	.56
	4-5	0.19	-.06	-.59	.47

Note. * $p < .05$ ** $p < .01$ *** $p < .001$. NART = National Adult Reading Test. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits.

Table 4.15

Odd ratios (OR) for group membership for the demographic measures in raw scores in the Lothian Birth Cohort 1936, with 95% confidence intervals (CI).

Variable	OR 2 (vs.1)	95% CI Lower	Upper	OR 3 (vs. 1)	95% CI Lower	Upper	OR 4(vs.1)	95% CI Lower	Upper	OR 5(vs.1)	95% CI Lower	Upper
Sex, males	1.31	0.3	3.25	1.40	0.66	2.99	0.89	0.42	1.89	1.45	0.58	3.61
Age 11 IQ	1.00	0.96	1.04	1.01	0.98	1.05	1.02*	0.99	1.06	0.99	0.95	1.03
NART	0.97	0.89	1.05	0.97	0.91	1.04	0.98	0.92	1.05	0.97	0.90	1.05
Years. in Education	1.56*	0.94	2.58	1.52**	0.99	2.32	1.41*	0.92	2.14	1.45*	0.87	2.42
Marital status, not married	0.79*	0.56	1.11	0.82*	0.62	1.08	0.71**	0.54	0.94	0.72**	0.50	1.04
Living status, alone	0.54*	0.16	1.88	1.42	0.50	4.05	.66	0.24	1.86	0.60	0.17	2.17
Social class, low	1.58*	0.90	2.79	1.38**	0.86	2.19	1.12	0.71	1.77	1.97	0.68	2.12

Note. The Low Wellbeing group is baseline *p*-values have been adjusted for multiple testing using Bonferroni correction. * $p < .05$ ** $p < .01$ *** $p < .001$. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits.

Table 4.16

Raw means, standard deviations (SDs), and significance values of neuroticism, extraversion, openness, agreeableness, and conscientiousness in the 5 groups in the Lothian Birth Cohort 1936.

Variables	1		2		3		4		5		df	F	*p*
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Means	SD			
Neuroticism	40.15	6.42	34.39	7.26	31.21	6.39	24.97	5.72	38.44	6.72	4	126.34	.001
Extraversion	32.13	6.72	35.90	5.14	38.04	5.71	40.88	5.39	36.10	4.81	4	36.01	.001
Openness	37.27	5.63	37.37	6.17	37.70	6.06	38.53	5.58	37.50	5.52	4	1.56	.183
Agreeableness	42.64	4.26	43.13	5.03	45.27	5.22	46.25	5.19	44.08	4.98	4	9.07	.001
Conscientiousness	44.72	7.05	41.37	6.81	46.27	5.78	48.19	5.56	42.94	5.56	4	28.02	.001

Note. No adjustment of significance levels for multiple testing. . 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits.

Table 4.17
Tukey's HSD post-hoc results for neuroticism, extraversion, agreeableness, and conscientiousness

Effect	Compare	Effect size	Mean difference	95% Confidence Interval	
		Cohen's *d*		Lower	Higher
Neuroticism	1-2	0.84	5.76***	2.09	9.45
	1-3	1.38	8.95***	5.85	12.06
	1-4	2.38	15.19***	12.11	18.27
	1-5	0.24	1.72	-2.12	5.56
	2-3	0.45	3.19**	.86	5.52
	2-4	1.39	9.43***	7.13	11.72
	2-5	0.62	-4.04**	-7.29	-.80
	3-4	1.00	6.24***	5.05	7.43
	3-5	1.15	-7.23***	-9.82	-4.64
	4-5	2.16	-13.47***	-16.02	-10.92
Extraversion	1-2	0.65	-3.77**	-7.09	-.46
	1-3	0.94	-5.91	-8.70	-3.13
	1-4	1.45	-8.75***	-11.51	-5.99
	1-5	0.60	-3.98*	-7.42	-.54
	2-3	0.36	-2.14*	-4.26	-.02
	2-4	0.92	-4.98***	-7.07	-2.89
	2-5	0.94	-.21	-3.14	2.73
	3-4	0.56	-2.84***	-3.91	-1.76
	3-5	0.40	1.94	-.39	4.26
	4-5	0.96	4.77***	2.48	7.06

Table 4.17 (continued)

Effect	Compare	Effect size Cohen's *d*	Mean difference	95% Confidence Interval	
				Higher	Lower
Agreeableness	1-2	0.23	-.49	-3.56	2.58
	1-3	0.68	-2.15*	-5.21	-.07
	1-4	0.93	-3.61***	-6.16	-1.07
	1-5	0.47	-1.45	-4.64	1.75
	2-3	0.39	-2.15*	-4.13	-.16
	2-4	0.60	-3.12***	-5.08	-1.17
	2-5	0.20	-.96	-3.70	1.79
	3-4	0.21	-.98*	-1.97	.02
	3-5	0.20	1.19	-.98	3.36
	4-5	0.43	2.16*	.02	4.31
Conscient-iousness	1-2	0.55	3.35	-.03	6.73
	1-3	0.22	-1.55	-4.40	1.30
	1-4	0.56	-3.07*	-6.30	-.65
	1-5	0.31	1.78	-1.74	5.30
	2-3	0.78	-4.90***	-7.06	-2.75
	2-4	1.14	-6.82***	-8.95	-4.70
	2-5	0.26	-1.57	-4.56	1.42
	3-4	0.36	-1.92***	-3.02	-.83
	3-5	0.54	3.33**	.96	5.71
	4-5	0.91	5.25***	2.91	7.60

Note. * $p < .05$ ** $p < .01$ $p < .001$. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits.

Table 4.18

Odd ratios (OR) for group membership for the personality measures of LBC1936 participants, with 95% confidence interval (CI).

Variable	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% C	
	2 (vs.1)	Lower	Upper	3(vs. 1)	Lower	Upper	4(vs.1)	Lower	Upper	5(vs.1)	Lower	U
Neuroticism	0.88***	0.81	0.94	0.84***	0.79	0.90	0.72**	0.67	0.77	0.98	0.91	1
Extraversion	1.08*	0.99	1.17	1.11***	1.03	1.19	1.17**	1.09	1.26	1.10**	1.02	1
Openness	0.99	0.91	1.07	.00	0.93	1.07	1.01	0.94	1.09	0.98	0.91	1
Agreeableness	1.02	0.93	1.11	1.07*	0.99	1.16	1.06*	0.98	1.15	1.06*	0.97	1
Conscientiousness	0.88***	0.81	0.95	1.00	0.93	1.06	0.99	0.93	1.06	0.94*	0.87	1

Note. *p*-values have been adjusted for multiple testing using Bonferroni correction. OR = Odds Ratio. CI = Confidence Interval. * $p < .05$ ** $p < .01$ *** $p < .001$. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits. The Low Wellbeing group is baseline.

Table 4.19

Raw means, standard deviations (SDs) and significance values for BMI and total units of alcohol per week for each of the 5 groups in the Lothian Birth Cohort 1936.

Variables	1		2		3		4		5				
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	df	F	*p*
BMI	29.35	5.31	28.98	5.22	27.75	4.52	27.61	4.10	27.76	4.80	4	2.46	.044
Units alcohol/wk	4.65	11.74	9.19	17.52	11.07	15.72	10.80	12.94	9.08	9.49	4	2.09	.080

Note. BMI = Body Mass Index. No adjustment of significance levels for multiple testing. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits. The Low Wellbeing group is baseline.

Table 4.20

Proportions, percentages and significance values for APOE e4 allele and smoking status in the five groups in the Lothian Birth Cohort 1936

Variables	1		2		3		4		5				
	N	%	N	%	N	%	N	%	N	%	df	F	*p*
APOE e4													
Not present	24	72.7	45	72.6	288	73.1	324	67.2	39	72.2			
Present	10	30.3	17	27.4	106	26.9	158	32.8	15	27.8			
N	33	100	62	100	394	100	482	100	54	100	4	.974	.421
Smoking category													
Never smoked	12	32.4	17	27.4	185	44.5	238	46.3	22	36.7			
Ex-smoker	16	43.2	28	45.2	179	43.	215	41.8	31	51.7			
Current smoker	9	24.3	17	27.4	52	12.5	61	11.9	7	11.7			
N	37	100	62	100	416	100	514	100	60	100	4	4.587	.001

Note. APOEe4 = Apolipoprotein E allele 4. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits.

Table 4.21

Tukey's HSD post-hoc results for BMI and Smoking category

Effect	Compare	Effect size Cohen's *d*	Mean difference	95% Confidence Interval Lower	Higher
BMI	1-2	0.15	.34	-2.16	2.85
	1-3	0.38	1.57	-.50	3.65
	1-4	0.38	1.71	-.34	3.77
	1-5	0.35	1.56	-.96	4.09
	2-3	0.22	1.23	-.41	2.87
	2-4	0.28	1.37	-.25	2.99
	2-5	0.20	1.22	-.97	3.46
	3-4	0.06	.14	-.66	.93
	3-5	0.01	-.01	-1.68	1.66
	4-5	0.07	-.15	-1.80	1.50
Smoking category	1-2	0.08	-.08	-.47	.31
	1-3	0.50	.23	-.08	.56
	1-4	0.52	.26	-.06	.58
	1-5	0.22	.17	-.22	.56
	2-3	0.44	.32**	.06	.58
	2-4	0.47	.34**	-.09	.60
	2-5	0.15	.25	-.09	.59
	3-4	0.01	.03	-.10	.15
	3-5	0.30	-.07	-.33	.19
	4-5	0.32	-.09	-.35	.16

Note. * $p < .05$ ** $p < .01$ *** $p < .001$. BMI = Body Mass Index.

Table 4.22

Odd ratios (OR) for group membership for health measures of LBC1936 participants, with 95% confidence interval (CI).

Variable	OR 2 (vs.1)	95% CI Lower	Upper	OR 3 (vs. 1)	95% CI Lower	Upper	OR 4(vs.1)	95% CI Lower	Upper	OR 5 (vs.1)	95% CI Lower	Upper
BMI	0.99	0.92	1.08	0.94*	0.87	1.00	0.93**	0.87	0.99	0.94*	0.86	1.02
APOE e4	0.85	0.33	2.16	0.78	0.35	1.70	1.03	0.47	2.23	0.83	0.32	2.15
Alcohol/ week	1.09*	1.02	1.16	1.11***	1.04	1.18	1.10	1.04	1.17	1.09**	1.02	1.17
Smoking	1.04	0.58	1.87	0.51**	0.31	0.84	0.49***	0.30	0.80	0.65*	0.35	1.18

Note. p values have been adjusted for multiple testing using Bonferroni correction. * $p < .05$ ** $p < .01$ *** $p < .001$. OR =Odds ratio. BMI = Body mass index. APOEe4 = Apolipoprotein E allele 4.

Table 4.23

Standardised means, standard deviations (SDs) and significance values for physical measures for each of the 5 groups in the Lothian Birth Cohort 1936.

Variables	1		2		3		4		5				
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	df	F	*p*
Grip strength	.31	3.05	-.11	.29	-.06	.26	.05	1.17	-.09	.27	4	1.94	.101
6m walk-time	1.19	1.98	.85	1.41	-.05	.90	-.16	.73	.19	1.38	4	30.46	.001
FEV_1	-.40	1.04	-.47	1.03	-.00	.94	.11	1.00	-.18	1.20	4	6.94	.001
FVC	-.33	.92	-.52	.93	.03	.96	.10	1.01	-.35	1.00	4	8.63	.001

Note. All variables here have been adjusted for sex, by saving the standardised residual from a linear regression with height as the independent variable and each of the above variables as the dependent variable. FEV_1 = forced expiratory volume in 1 second. FVC = forced vital capacity. 6 m = 6 meters. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits.

Table 4.24
Tukey's HSD post-hoc results for walk time, FEV_1 and FVC

Effect	Compare	Effect size Cohen's *d*	Mean difference	95% Confidence Interval Lower	Higher
Walk time	1-2	0.22	.33	-.21	.89
	1-3	0.91	1.24***	.78	1.70
	1-4	0.99	1.35***	.89	1.80
	1-5	0.58	1.00***	.45	1.55
	2-3	0.72	.90***	.55	1.26
	2-4	0.82	1.01***	.66	1.36
	2-5	0.38	.66**	.19	1.13
	3-4	0.20	.11	-.06	.28
	3-5	0.36	-.24	-.60	.12
	4-5	0.48	-.35	-.71	.01
FEV_1	1-2	0.08	.07	-.49	.63
	1-3	0.48	-.40	-.86	.07
	1-4	0.58	-.51*	-.97	-.05
	1-5	0.15	-.22	-.78	.35
	2-3	0.53	-.47**	-.83	-.10
	2-4	0.63	-.657***	-.94	-.21
	2-5	0.21	-.29	-.78	.21
	3-4	0.09	-.11	-.29	.07
	3-5	0.27	.18	-.20	.56
	4-5	0.36	.29	-.08	.66

Table 4.24 (continued)

Effect	Compare	Effect size Cohen's *d*	Mean difference	95% Confidence Interval Lower	 Higher
FVC	1-2	0.21	.18	-.37	.75
	1-3	0.49	-.36	-.82	.10
	1-4	0.51	-.43	-.89	.03
	1-5	0.07	.02	-.55	.59
	2-3	0.65	-.55***	-.92	-.18
	2-4	0.67	-.62***	-.98	-.26
	2-5	0.11	-.17	-.66	.32
	3-4	0.02	-.07	-.25	.11
	3-5	0.49	.38*	-.01	.76
	4-5	0.51	.45**	.08	.82

Note. FEV_1 = Forced expiratory volume in 1 second. FVC = Forced vital capacity. . 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits

Table 4.25

Odd ratios (OR) for group membership for physical measures of Lothian Birth Cohort 1936 participants, with 95% confidence interval (CI).

Variable	OR 2 (vs.1)	95% CI Lower	Upper	OR 3 (vs. 1)	95% CI Lower	Upper	OR 4 (vs.1)	95% CI Lower	Upper	OR 5 (vs.1)	95% CI Lower	Upper
Grip strength	0.82	0.54	1.24	0.62*	0.37	1.03	0.89*	0.78	1.03	0.65	0.23	1.84
Walk time	0.90	0.72	1.12	0.50***	0.40	0.64	0.44***	0.34	0.57	0.65*	0.47	0.89
FEV_1	1.46	0.71	3.00	1.20	0.67	2.17	1.37	0.76	2.46	2.23**	1.04	4.82
FVC	0.57*	0.26	1.21	1.10	0.59	2.03	1.01	0.55	1.86	0.45*	0.20	1.01

Note. *p*-values have been adjusted for multiple testing using Bonferroni correction. * $p < .05$ ** $p < .01$ *** $p < .001$ = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits. The Low Wellbeing group is baseline.

Table 4.26

Means and significance values for each of the groups for the disease measures in the Lothian Birth Cohort 1936.

Variables	1		2		3		4		5				
	N	%	N	%	N	%	N	%	N	%	df	F	*p*
High BP													
Yes	20	54.1	35	56.5	172	41.3	187	36.4	17	28.3			
No	17	45.9	27	43.5	244	58.7	327	63.6	43	71.7			
N	37	100	62	100	415	100	517	100	61	100	4	4.18	.002
Diabetes													
Yes	13	35.1	13	21	34	8.2	27	5.3	4	6.7			
No	24	64.9	49	79	382	91.8	487	94.7	56	93.7			
N	37	100	62	100	416	100	514	100	61	100	4	14.20	.001
CVD													
Yes	19	51.4	23	37.1	99	23.8	108	21	18	70			
No	18	48.6	39	62.9	317	76.2	406	79	42	30			
N	37	100	62	100	416	100	517	100	61	100	4	6.16	.001
Blood Cicr Problems													
Yes	7	18.9	16	25.8	58	14	68	13.2	7	11.7			
No	29	78.7	46	74.2	356	86	446	86.8	53	88.3			
N	36	100	62	100	414	100	514	100	61	100	4	2.08	.082
History of Stroke													
Yes	4	10.8	6	9.7	22	5.3	16	3.1	6	10			
No	33	89.2	56	90.3	394	94.7	498	96.9	54	90			
N	37	100	62	100	415	100	514	100	61	100	4	3.19	.024

Note. BP = blood pressure. CVD = cardiovascular disease. ** $p < .01$. *Note.* No adjustment of significance levels for multiple testing. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits. The Low Wellbeing group is baseli

Table 4.27
Tukey's HSD post-hoc results on high blood pressure, diabetes, CVD, and stroke

Effect	Compare	Effect size Cohen's *d*	Mean difference	95% Confidence Interval Lower	 Higher
High blood pressure	1-2	0.04	-.02	-.30	.25
	1-3	0.34	.13	-.10	.36
	1-4	0.43	.18	-.05	.40
	1-5	0.58	.26	-.02	.54
	2-3	0.30	.15	-.03	.33
	2-4	0.39	.20*	.02	.38
	2-5	0.54	.28*	.04	.52
	3-4	0.08	.05	-.04	.14
	3-5	0.23	.13	-.05	.31
	4-5	0.15	.08	-.10	.26
Diabetes	1-2	0.33	.14	-.01	.30
	1-3	0.70	.27***	.14	.40
	1-4	0.82	.30***	.17	.42
	1-5	0.70	.29***	.13	.44
	2-3	0.37	.13**	.03	.23
	2-4	0.48	.16***	.06	.26
	2-5	0.37	.16*	.01	.28
	3-4	0.12	.03	-.02	.08
	3-5	0	.01	-.09	.12
	4-5	0.12	-.01	-.11	.09

Table 4.27 (continued)

Effect	Compare	Effect size Cohen's *d*	Mean difference	95% Confidence Interval Lower	 Higher
CVD	1-2	0.36	.14	-.10	.38
	1-3	0.68	.28**	.08	.48
	1-4	0.73	.30***	.11	.50
	1-5	0.51	.21	-.03	.46
	2-3	0.31	.13	-.03	.29
	2-4	0.35	.16*	.00	.32
	2-5	0.14	.07	-.14	.28
	3-4	0.05	.03	-.05	.10
	3-5	0.16	-.06	-.25	.10
	4-5	0.21	-.09	-.25	.07
Stroke	1-2	0.06	.01	-.11	.13
	1-3	.029	.06	-.05	.16
	1-4	0.30	.08	-.02	.18
	1-5	0.06	.01	-.12	.13
	2-3	0.24	.04	-.04	.12
	2-4	0.24	.07	-.01	.15
	2-5	0	-.00	-.11	.10
	3-4	0	.02	-.02	.06
	3-5	0.24	-.05	-.13	.03
	4-5	0.24	-.07	-.15	.01

Note. *CVD* = Cardiovascular disease. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits. The Low Wellbeing group is baseline.

Table 4.28

Odd ratios (OR) for group membership for presence of disease of Lothian Birth Cohort 1936 participants, with 95% confidence interval (CI)

Variable	OR 2 (vs.1)	95% CI Lower	95% CI Upper	OR 3(vs. 1)	95% CI Lower	95% CI Upper	OR 4(vs.1)	95% CI Lower	95% CI Upper	OR 5(vs.1)	95% CI Lower	95% CI Upper
High BP	1.51	0.61	3.70	1.04	0.49	2.22	0.90	0.42	1.93	0.51*	0.20	1.29
Diabetes	0.46*	0.17	1.22	0.18***	0.08	0.41	0.13***	0.05	0.29	0.16***	0.05	0.58
CVD	0.53*	0.22	1.25	0.31***	0.15	0.65	0.29***	0.14	0.59	0.51*	0.21	1.24
Blood circulation problems	1.34	0.49	3.71	0.57*	0.23	1.40	0.52*	0.21	1.27	0.45*	0.14	1.45
Stroke	0.95	0.24	3.76	0.65	0.20	2.13	0.40*	0.12	1.37	1.48	0.36	6.04

Note. *p*-values have been adjusted for multiple testing using Bonferroni correction. * $p < .05$ ** $p < .01$ *** $p < .001$. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits. BP =Blood Pressure. CVD = Cardiovascular disease. The Low Wellbeing group is baseline.

Table 4.29

Standardised means, standard deviations (SDs) and significance values for cognitive ability for each of the 5 groups in the Lothian Birth Cohort 1936.

Variables	1		2		3		4		5				
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	df	F	Sig.
g	-.45	.79	-.24	.73	-.04	.72	.13	.70	-.23	.71	4	11.13	.000
Memory	-.05	.84	-.04	.82	-.02	.82	.07	.79	-.21	.92	4	2.00	.093
Speed	-.26	.72	-.14	.42	-.01	.57	-.04	.53	.17	.60	4	4.23	.002

Note. g = general cognitive ability. No adjustment of significance levels for multiple testing. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits. The Low Wellbeing group is baseline.

Table 4.30

Tukey's HSD post-hoc results for g and speed.

Effect	Compare	Effect size	Mean difference	95% Confidence Interval	
		Cohen's *d*		Lower	Higher
g	1-2	.50	-.22	-.62	.19
	1-3	.74	-.41**	-.75	-.08
	1-4	.96	-.58***	-.91	-.25
	1-5	.52	-.21	-.63	.19
	2-3	.22	-.20	-.47	.07
	2-4	.44	-.36**	-.63	-.09
	2-5	.01	-.00	-.36	.36
	3-4	.23	-.16**	-.29	-.03
	3-5	.21	.20	-.08	.47
	4-5	.43	.36**	.09	.63
Speed	1-2	.58	.40*	.05	.74
	1-3	.37	.27	-.02	.56
	1-4	.39	.29*	.01	.58
	1-5	.03	.09	-.25	.44
	2-3	.20	-.13	-.34	.08
	2-4	.19	-.10	-.31	.10
	2-5	.60	-.31*	-.59	-.02
	3-4	.02	.02	-.08	.12
	3-5	.37	-.18	-.40	.04
	4-5	.40	-.20	-.42	.01

Note. * $p < .05$ ** $p < .01$ *** $p < .001$. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits. The Low Wellbeing group is baseline

Table 4.31

Odd ratios (OR) for group membership of Lothian Birth Cohort 1936 participants, with 95% confidence interval (CI).

Variable	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
	2 (vs.1)	Lower	Upper	3 (vs. 1)	Lower	Upper	4 (vs.1)	Lower	Upper	5(vs.1)	Lower	Upper
g	1.05	0.49	2.26	1.96*	1.02	3.76	2.62**	1.37	4.02	1.43	0.66	3.10
Memory	0.70	0.36	1.36	0.67	0.38	1.17	0.67	0.38	1.18	0.62	0.32	1.20
Speed	0.30**	0.14	0.68	0.58*	0.31	1.10	0.58*	0.31	1.10	0.82	0.39	1.73

Note. *p* values have been adjusted for multiple testing using Bonferroni correction. * $p < .05$ ** $p < .01$ *** $p < .001$. 1 Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits. The Low Wellbeing group is baseline.

Table 4.32

Raw means, standard deviations (SDs) and significance values for total number of medications and number of medical conditions for each of the 5 groups in the Lothian Birth Cohort 1936.

Variables	1		2		3		4		5				
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	df	F	*p*
Medication total	5.43	2.62	4.82	2.80	2.99	2.41	2.52	2.30	3.18	2.81	4	23.17	.001
Medical conditions	5.17	1.87	4.42	1.74	3.37	1.70	2.76	1.55	3.07	1.74	4	31.78	.001

Note. No adjustment of significance levels for multiple testing. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits

Table 4.33

Tukey's HSD post-hoc results for total amount of medication taken and total number of medical conditions

Effect	Compare	Effect size Cohen's *d*	Mean difference	95% Confidence Interval Lower	Higher
Medication total	1-2	.32	.61	-.76	1.98
	1-3	1.02	2.43***	1.30	3.57
	1-4	1.20	2.91***	1.78	4.03
	1-5	.79	2.25***	.87	3.63
	2-3	.66	1.82***	.93	2.72
	2-4	.83	2.30***	1.41	3.19
	2-5	.47	1.64**	.44	2.84
	3-4	.17	.47*	.04	.91
	3-5	.16	-.19	-1.10	.73
	4-5	.32	-.66	-1.56	.24
Medical conditions	1-2	.49	.49	-.19	1.69
	1-3	1.14	1.79***	1.02	2.57
	1-4	1.53	2.41***	1.64	3.18
	1-5	1.13	2.10***	1.16	3.04
	2-3	0.63	1.04***	.43	1.66
	2-4	1.00	1.66***	1.05	2.27
	2-5	0.65	1.35***	.53	2.17
	3-4	0.34	.62***	.32	.91
	3-5	0.06	.31	-.31	.92
	4-5	0.56	-.31	-.92	.30

Note. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits.

Table 4.34

Odd ratios (OR) of group membership for medication and medial conditions of Lothian Birth Cohort 1936 participants, with 95% confidence interval (CI).

Variable	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
	2 (vs.1)	Lower	Upper	3 (vs. 1)	Lower	Upper	4(vs.1)	Lower	Upper	5(vs.1)	Lower	Upper
Drugs total	0.97	0.80	1.18	0.80**	0.67	0.94	0.81**	0.69	0.96	0.89	0.73	1.09
Medical conditions	0.82	0.63	1.07	0.69***	0.55	0.87	0.54***	0.43	0.68	0.56***	0.42	0.75

Note. *p*-values have been adjusted for multiple testing using Bonferroni correction. $p < .05$ ** $p < .01$ *** $p < .001$. 1 = Low Wellbeing. 2 = Low Function/High Spirits. 3 = Average Wellbeing. 4 = High Wellbeing. 5 = High Function/Low Spirits. The Low Wellbeing group is baseline.

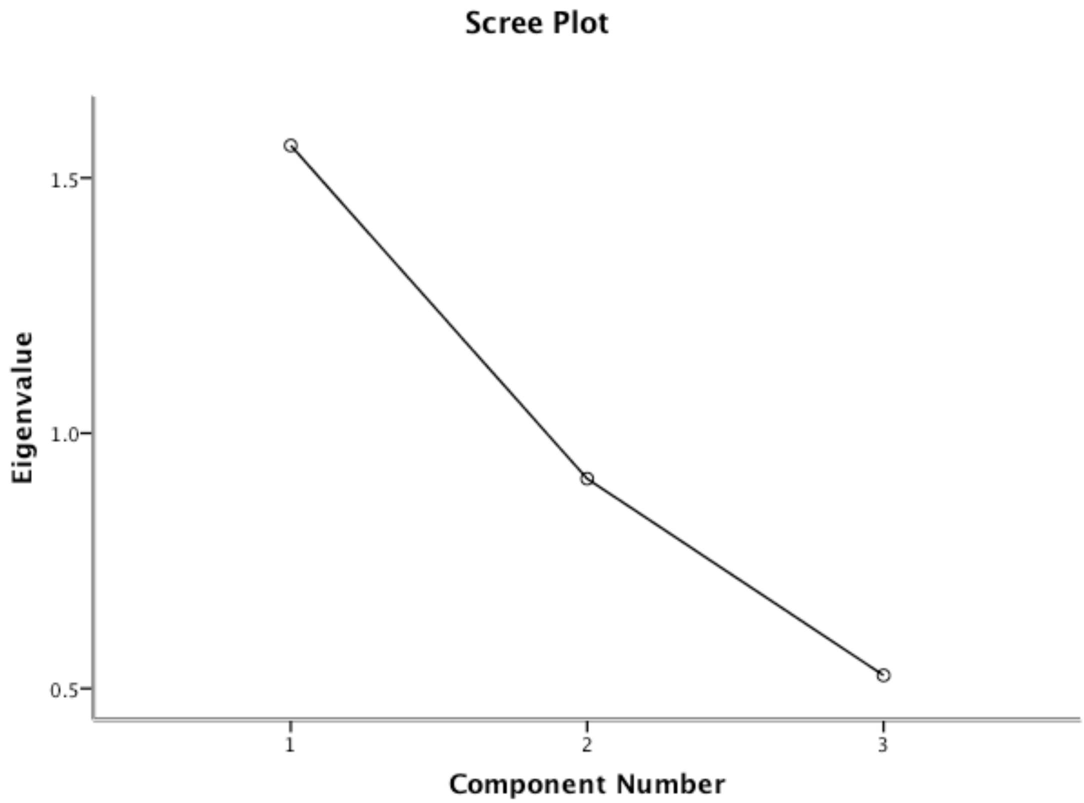


Figure 4.1 The scree plot for Physical Function displaying inflexions that would justify retaining one component.

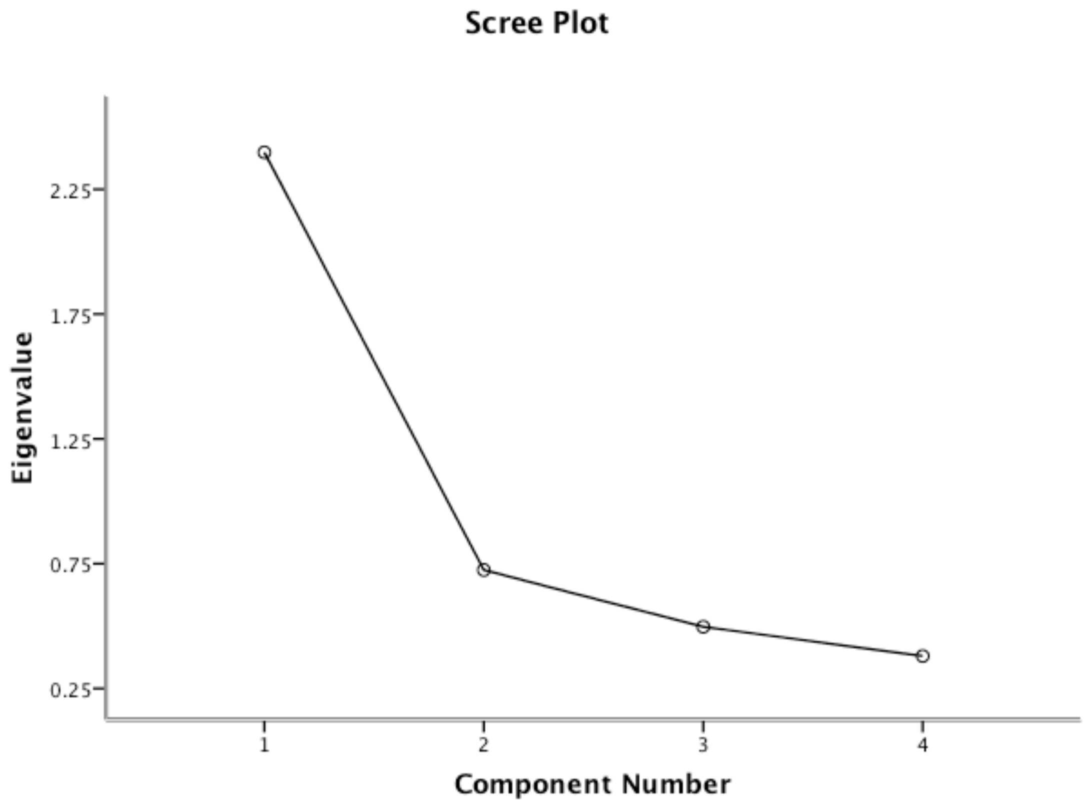


Figure 4.2. The scree plot for Quality of Life displaying inflexions that would justify retaining one component.

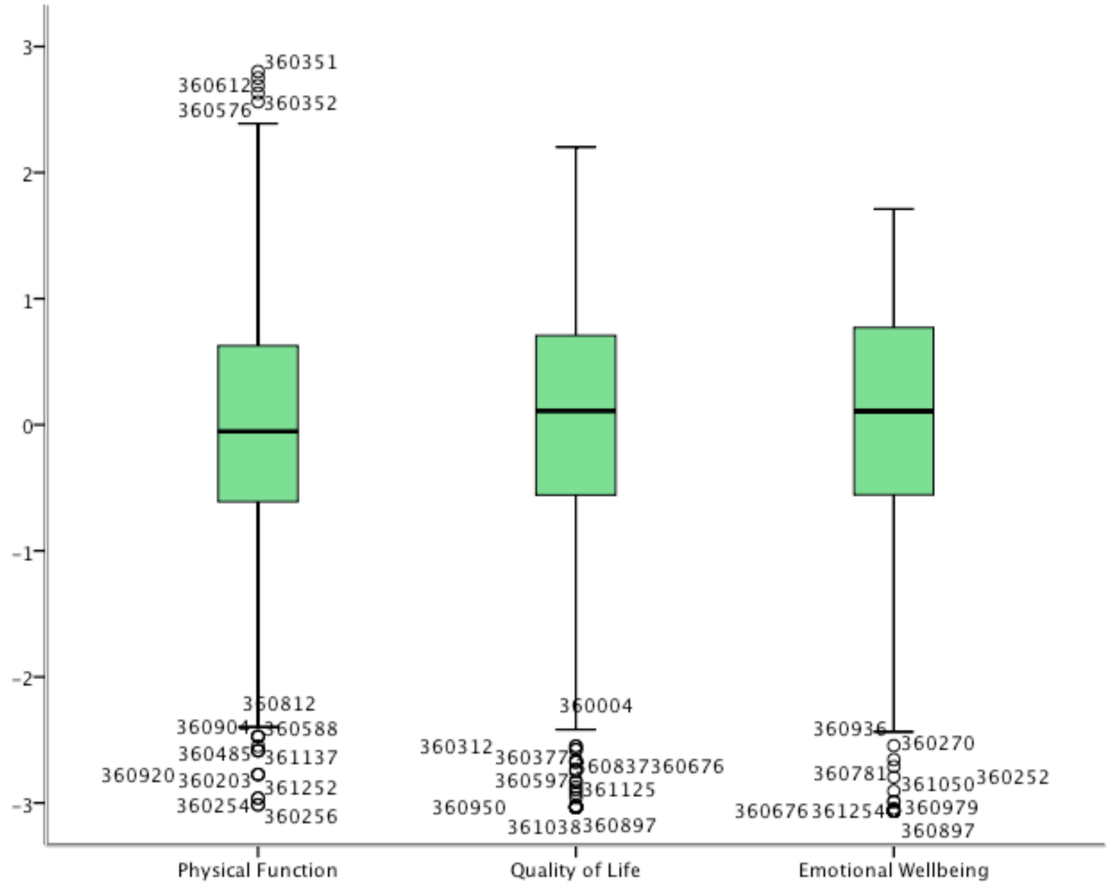


Figure 4.3. The boxplots of the psychosocial wellbeing components retained from PCA with winsorised scores.

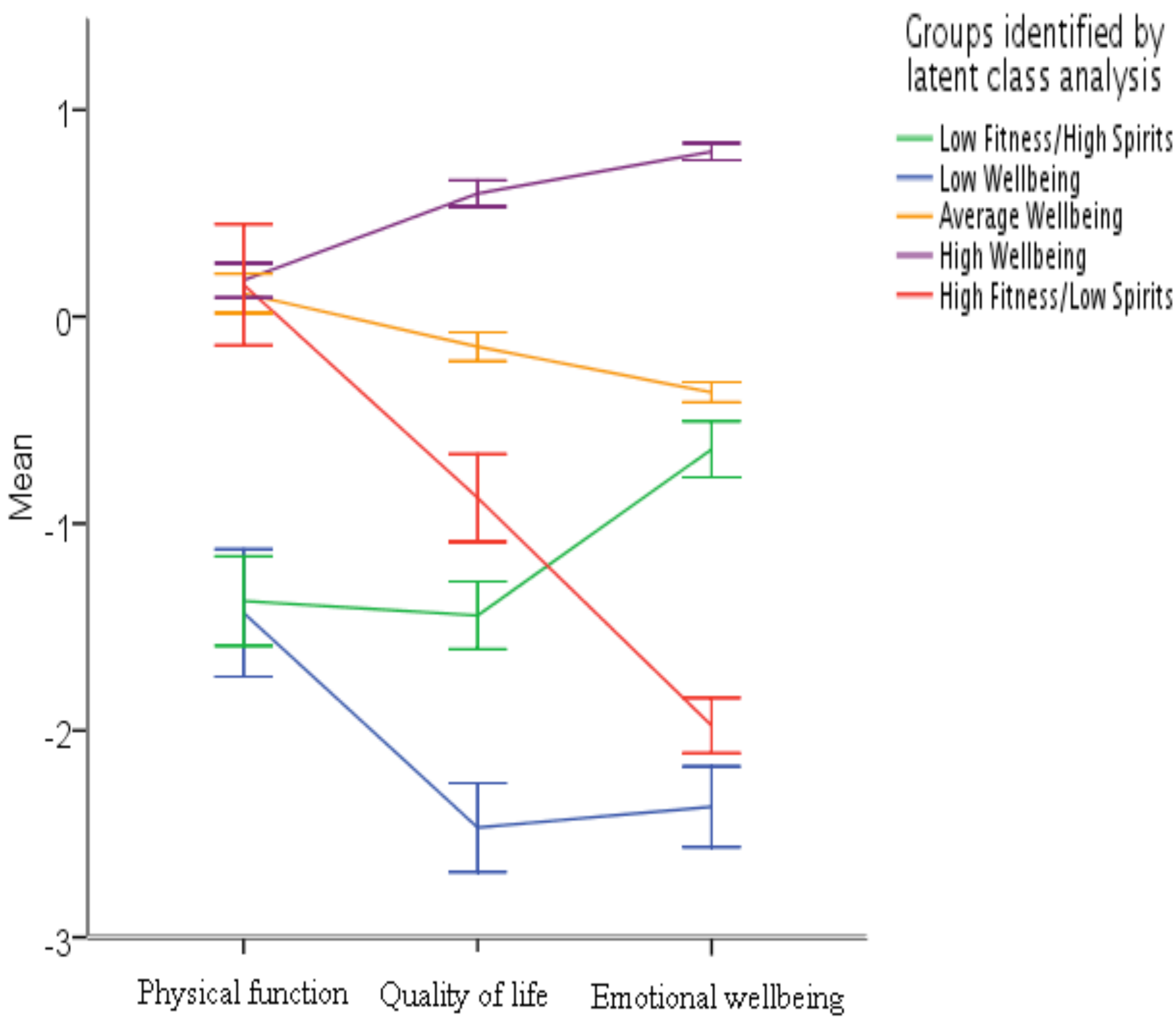


Figure 4.4. The groups' mean scores on each of the psychosocial components, namely Physical Function, Quality of Life, and Emotional Wellbeing, with 95% confidence intervals, as generated from latent class analysis for the LBC1936.

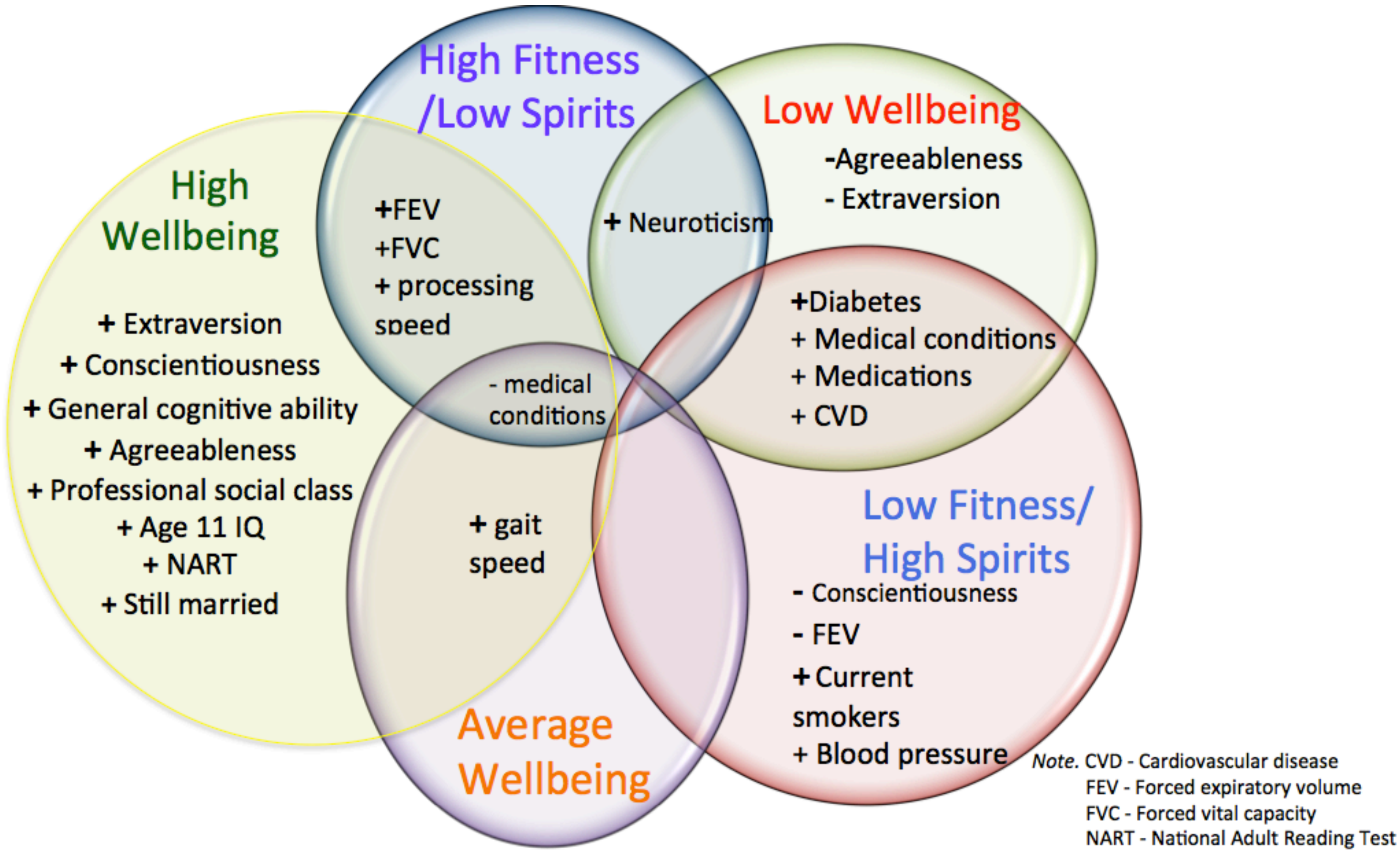


Figure 4.5. Venn diagram displaying common and distinctive significant features characterising the groups

5. The Physical Fitness Domain

In the previous chapters, I derived three cognitive components and three psychosocial components representing major domains of cognitive ability and psychosocial wellbeing from principal components analysis (PCA). I then used these to group and classify individuals in the Lothian Birth Cohort 1936 according to their scores on these components.

In this chapter, I took a similar approach in an attempt to identify and group individuals according to their wellbeing in another major domain representing health in old age: Physical Fitness, as determined by the variables that have been shown to affect this domain in old age - physical fitness, inflammation, and morbidity (e.g. Deary, Whalley, Batty, et al., 2006; DiPietro, 2001; Christensen, Mackinnon, Korten, et al., 2001; Mendall, Strachen, Butland, et al., 2000; Starr, Deary, Lemmon & Whalley, 2000). These provide objective information, and have been shown to correlate with cognitive ageing (Anstey et al., 1996; Anstey & Smith, 1999; Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994; Starr, 1999). It will be interesting to find out if patterns of groupings here are similar to those obtained from the Cognitive Ability domain. Therefore, I first identified *a priori* some key variables to explore whether there are separable groups with respect to physical fitness, inflammation and morbidity at age 70 in the LBC1936. I used latent class analysis (LCA) to extract groups of individuals based on their scores on these components. Finally I investigated whether the groups I identified showed important associations with 'external' variables relating to demographic measures, prior cognitive ability, personality measures, general health measures, quality of life, emotional wellbeing and current cognitive ability.

5.1 Formation of the physical components

In this section a description of the physical components of Physical Fitness, Inflammation, and Morbidity in the LBC1936, is described. Note that in this chapter the Physical Fitness component uses a different set of variables, which are more physiological-based than the ones used to construct the Physical Function component in the Psychosocial Domain.

5.1.1 Physical Fitness

Variables constituting the Physical Fitness component included the best of three trials in grip strength with the dominant hand, forced expiratory volume in 1 second (FEV_1), and 6-metre walk time. Similar variables have also been used in previous research as a fitness component, and have been found to be associated with healthy cognitive ageing (Deary, Whalley, Batty, et al., 2011). All three variables were adjusted for sex and height. I used the inverse of the 6-metre walk-time to equate higher scores with a faster gait-speed. This variable was also renamed, *gait speed*. A more thorough description of these variables can be found in Chapter 2, entitled *Methodology*. Table 5.1 shows the raw means and standard deviations (SDs) of all the participants (n = 1076) who completed the physical examinations, including scores for males and females separately. Males scored higher across all variables, emphasising the importance of adjusting for height and sex.

Pearson's correlation coefficients were then computed to test the relations among these three variables. This is shown in Table 5.2. The correlation matrix shows that all markers of Physical Fitness correlated significantly at $p < .01$. The correlation coefficients ranged from .23 between grip strength and gait speed, to .32 between FEV_1 and grip strength, with a mean correlation of .27.

A principal components analysis using maximum likelihood estimation was conducted on the three variables measuring Physical Fitness, using an unrotated solution. The Kaiser-Meyer-Olkin measure of sample adequacy for the analysis was .61, which is above the acceptable limit of .5 (Field, 2009). Bartlett's test of sphericity χ^2 (3) = 217.55, p < .001, indicated that correlations between subtests were sufficiently large for principal components analysis. An initial analysis was run to obtain eigenvalues for the components in the data. There was only one component and it had an eigenvalue over Kaiser's criterion of 1. This explained 51.38% of the total variance. Examination of the scree plot showed inflexions that would also justify retaining 1 component. This can be seen in Figure 5.1. All subtests loaded over .68. This can be seen in Table 5.3. The three variables were analysed for internal consistency estimates using Cronbach's alpha. The obtained value was .53.

5.1.2 Inflammation

Variables constituting the inflammation component included C-Reactive Protein (CRP), Neutrophil count, and Fibrinogen. Inflammation markers, such as these, have shown associations between their presence in plasma levels and development of dementia (Schmidt, Schmidt, Curb, et al., 2002; Engelhart, Geerlings, Meijer, et al., 2004), depression (Berk, Wadee, Kuschke & O'Neill-Kerr, 1997; Miller, Stetlet, Carney, Freedland & Banks, 2002), and cardiovascular disease (Mendall, Strachan, Butland, et al., 2000). A more thorough description of these variables can be found in Chapter 2, entitled *Methodology*. Table 5.4 shows the raw means and standard deviations (SDs) of all the participants (n = 1039) who completed the tests, including scores for males and females separately. Females tended to show higher scores on CRP and Neutrophil count, but not on Fibrinogen.

Pearson's correlation coefficients were then computed to test the relations among these three variables. This is shown in Table 5.5. The correlation matrix shows that all markers of Inflammation correlated significantly with each other at $p < .01$. The correlation coefficients ranged from .31 between Fibrinogen and Neutrophil count, to .48 between CRP and Fibrinogen, with a mean correlation of .38.

A principal components analysis using maximum likelihood estimation was conducted on the three variables measuring inflammation, using an unrotated solution. The Kaiser-Meyer-Olkin measure of sampling adequacy was .63, which is above the acceptable limit of .5 (Field, 2009). Bartlett's test of sphericity χ^2 (3) = 431.93, $p < .001$, indicated that correlations between subtests were sufficiently large for principal components analysis. An initial analysis was run to obtain eigenvalues for the components in the data. There was only one component with an eigenvalue over Kaiser's criterion of 1. This explained 58.59% of the total variance. Examination of the scree plot showed inflexions that would also justify retaining 1 component. This can be seen in Figure 5.2. All subtests loaded over .39. This can be seen in Table 5.6. The three variables were analysed for internal consistency estimates using Cronbach's alpha for reliability analysis. The obtained internal consistency was .64.

5.1.3 Morbidity

To measure morbidity, 1091 participants were interviewed for their medical history, and for any regular medication taken. For their medical history participants were specifically asked if they had histories of high blood pressure, diabetes, high cholesterol, cardiovascular disease, leg pain, blood circulation problems, stroke, cancer, thyroid, Parkinson's disease, arthritis, gout, or any other disease that had not been mentioned. Participants were also asked to name all medications they were taking at the time. These were then summed for each participant, and 2 variables were created, one for total number of medical conditions and the other for total number of medication taken. Table 5.7 shows the raw means and standard deviations (SDs) of all participants, including for males and females separately. The range spanned from 0 to 8 for total number of medications, and from 0 to 10 medical conditions for the whole population with a median of 3.0 for each variable.

The two subtests correlated significantly with each other at $p < .001$ with a correlation of .64. The two subtests were then standardised and their mean was calculated. Their average was again standardised and used as the Morbidity composite.

5.1.4 The Physical Fitness components

The three physical variables: Physical Fitness, Inflammation, and Morbidity that were derived from principal components analysis, were tested for normality using boxplots. Each component showed outliers; however, these were winsorised. Therefore, any score that fell above or below three standard deviations was adjusted to either -3 or +3 standard deviations, depending on whether the outlier was below or above the mean respectively. Inflammation and Morbidity were reversed to change the direction of scores in a way to equate higher scores with better physical health. These were now called Lack of Inflammation, and Lack of Morbidity. All of the variables were restandardised after any adjustments made to them, such as reversal or winsorising. A boxplot with winsorised scores and the reversed Inflammation, and Morbidity variables can be seen in Figure 5.3.

Pearson's correlation coefficients were computed for the three Physical Fitness components. Physical Fitness and Morbidity were statistically significantly correlated at $p < .01$, but no other correlations were statistically significant. The correlation table can be seen in Table 5.8.

5.2 Formation of groups using latent class analysis

In section 5.1 I derived three broad areas of Physical Fitness, representing Physical Fitness, Lack of Inflammation, and Lack of Morbidity from principal components analysis. I standardised and analysed these as z-scores (M = 0, SD = 1) throughout the whole study to avoid complications comparing results. The physical components have already been checked for normality in a previous section (Section 5.1.3). The aim of extracting these components was to apply them to latent class analysis and attempt to identify subgroups of individuals within the LBC1936 based on their response measures. To identify physical profiles in the LBC1936, I ran a latent class analysis using participants' component scores on Physical Fitness, Lack of Inflammation, and Lack of Morbidity.

Two-, three-, four-, and five- class solutions were defined in the latent class models and run using MPlus (Muthen & Muthen, 2004). Solutions that included less than 5% of the population were avoided. The most parsimonious solution was also sought. The results from these solutions were compared using the Akaike information criterion (AIC), the Bayesian information criterion (BIC), and the adjusted BIC. Table 5.9 shows the BIC values for these models, indicating minimisation of the BIC at 2 groups. The ENT had a maximum of .709 at 5 groups and a minimum of .665 at 3 groups. The 2- and 4- group solutions had ENTs of .689 and .682. Despite having the best ENT, the 5-group solution contained groups with less than 5% of the population. The 3- and 4-group solutions had a lower ENT than the 2-group solution. The 2-group solution also grouped together two groups from the 3-group solution with similar trends into one. This group seemed to explain population trends in a simpler yet more comprehensive way than the 3-group solution. Furthermore, the sample seemed to be divided into a large high performing group, and a smaller group doing less well on physical wellbeing. The 2-group solution had the best model-fit, and seemed as the most parsimonious, so I decided to explore this solution within the sample. Participants were assigned to the group to which they had the highest probability of belonging according to their responses on Physical Fitness, Lack of Inflammation, and Lack of Morbidity measures as depicted by LCA. For most likely group membership, the probabilities ranged from .86 to .93, indicating clear group membership for the majority of participants. Table 5.10 illustrates class membership probabilities as they were predicted by LCA.

5.2.1 Profiles of the latent groups

The 2-group solution was selected for further analysis. Table 5.11 shows the means and standard deviations for each group on scores of Physical Fitness, Lack of Inflammation, and Lack of Morbidity. Group 1 had low scores on Physical Fitness and Lack of Morbidity, but average scores on Lack of Inflammation, whereas Group 2 had high scores on Physical Fitness and Lack of Morbidity, but average scores on Lack of Inflammation. Both groups had similar scores on Lack of Inflammation. This result showed that the inflammation variable was not informative in this sample. The majority of individuals were in Group 2 (n = 800, 73.3%), which was labelled the High Physical Wellbeing group. The remaining 26.7% (n = 291) were in Group 1, labelled the Low Physical Wellbeing group. A plot of their means can be seen in Figure 5.4.

Similar to previous results from the Cognitive domain, the Physical domain also seemed to suggest a continuous pattern of wellbeing across groups (i.e. ranging from low to high wellbeing). Further, the similar means from both groups on the Lack of Inflammation suggests that the variable is not giving much information, or is useful to explore differences amongst participants. Nevertheless, exploring any group differences using external variables was still an aim worth carrying out to find out more about the groups.

5.3 Descriptors and predictors of Physical Fitness at age 70

In the previous section I applied LCA to the LBC1936 with the aim of generating groups of 70-year old individuals according to their Physical Fitness, Lack of Inflammation, and Lack of Morbidity. Results supported a 2-group solution consisting of low and high physical wellbeing. The majority fell in the High Physical Wellbeing group (73.3%), however, a substantial number fell in the Low Physical Wellbeing group (26.7%). Results also indicated dimensional classifications.

In this section, I explored how individuals at the lower end of the spectrum differed from individuals at the higher end on a number of variables relating to demographic and prior cognitive ability measures, personality, cognitive ability, and psychosocial wellbeing. These variables were chosen to provide descriptive data relating to more specific cognitive and psychosocial information for each of both groups, and to find out what distinguishes amongst them. These variables were referred to as descriptors and predictors of physical fitness at age 70.

A thorough description of all the variables mentioned in this chapter can be found in chapter 2, entitled *Methodology*. In all instances, independent t-tests were first used to find out if significant differences were present amongst the groups on any of the variables. This was followed by logistic regression with the aim of predicting group membership for each of the variables that were being analysed.

In the next section, both groups are described and compared against each other in terms of the aforementioned sets of variables. A summary of results is then presented.

5.3.1 Demographic measures and prior cognitive ability

Pre-morbid and current mental ability, level of education and social class are correlates of health, morbidity and mortality in old age (Starr, Deary, Lemmon & Whalley, 2000; Fried, Ettinger, Lind et al., 1994; Gale, Martyn & Cooper, 1996; Breeze, Fletcher, Leon, et al., 2001; Arber & Ginn, 1993).

In this study, the demographic measures used to describe the 2 groups included sex, age-11 IQ, the National Adult Reading Test (NART), total number of years in formal education, marital status, and living status. These were included in the t-test as dependent variables and the group number as the independent variable.

Significant differences amongst the groups were found for age-11 IQ, the NART, and total number of years of formal education with the High Physical Wellbeing class scoring higher on all variables. Tables 5.12 and 5.13 show the raw means and standard deviations along with the t-test results of the continuous and categorical demographic variables for each of the two groups respectively.

Logistic regression was then run using the same variables to find out whether any of these were predicting group membership in the two groups. Results showed that for every unit increase in NART scores, the odds of belonging to the High Physical Wellbeing group rather then the Low Physical Wellbeing group were 1.04 times as great. None of the other variables showed any significant results. Table 5.14 shows the results.

5.3.2 Personality measures

Personality is a strong outcome of health and wellbeing (Costa & McCrae, 1980; Isaacowitz & Smith, 2003). Neuroticism has been associated with higher risk of mortality in both healthy individuals and in individuals with medical conditions (Christensen, Ehlers, Wiebe, et al., 2002; Smith, Glazer, Ruiz, et al., 2004; Denollet, Sys, & Brutsaert, 1995; Wilson, Mendes de Leon, Bienias et al., 2004). It has been shown to double mortality risk (Wilson et al., 2004). On the other hand, conscientiousness has been shown to lower the risk of mortality by half (Wilson et al., 2004). Other personality traits, including Openness, Agreeableness and Extraversion have not shown striking results with regards to morbidity and mortality (Wilson et al., 2004).

The NEO-PI-R inventory was used to study personality measures in this sample and to describe the two groups. This included measures on Neuroticism, Extraversion, Openness, Consciousness, and Agreeableness. These were included in the t-tests as dependent variables and the groups as the independent variable. Significant differences amongst the groups were found for Neuroticism, Extraversion, Agreeableness, and Conscientiousness, with the High Physical Wellbeing group showing higher scores on all variables except for Neuroticism. Table 5.15 shows the raw means and standard deviations along with the t-test results of the two groups.

A logistic regression was applied to find out if any of the personality traits predicted class membership. Results showed that for every unit increase in Neuroticism the odds of belonging in the High Physical Wellbeing class were lower (OR = 0.96). Table 5.16 shows the results.

5.3.3 Health measures

Major determinants of burden of disease include high body mass index (BMI), lack of physical activity, bad diet, smoking, high blood pressure, and high cholesterol (WHO, 2002; Ezzati, Lopez, Rodgers, et al., 2002). Although health inevitably alters with increasing age, health behaviours such as dietary habits, physical activity and smoking behaviour may affect the risk of diabetes, heart disease, hypertension and some cancers (Drewnowski & Evans, 2001). Frequent alcohol drinking is associated with harmful effects on the brain. Furthermore, individuals carrying the *APOE* e4 allele have a higher risk of developing dementia with increasing alcohol consumption (Anttila, Helkala, Viitanen, et al., 2004).

In this study units of alcohol consumed per week, body mass index (BMI), smoking category (smoker, non-smoker, ex-smoker), and presence/absence of APOE e4 allele were used to explore differences between the 2 groups. Significant differences were found for BMI and smoking status, with individuals in the High Physical Wellbeing group showing a lower BMI, and a lower percentage of ex and current smokers. Tables 5.17 and 5.18 show the results.

A logistic regression was applied to find out if any of the variables predicted group membership. Results showed that individuals in the High Physical Wellbeing group were less likely to have high BMI High (OR = 0.90) and were less likely to be smokers (OR = .64). Table 5.19 shows the results.

5.3.4 Cognitive measures

The association between cognitive ability and physical fitness is well established (Deary, Whalley, Batty & Starr, 2006; Cook, Albert, Berkman, Blazer, et al., 1995; Christensen, Mackinnon, Korten & Jorm, 2001; Anstey & Smith, 2003; MacDonald, Dixon, Cohen & Hazlitt, 2004; Gale, Martyn & Cooper, 1996). The use of medications also has a detrimental effect on cognitive ability (Starr, McGurn, Whiteman et al., 2004).

In this study, three variables relating to cognitive ability, namely General Cognitive Ability (*g*), Memory, and Speed, were used to analyse the 2 groups. These variables have already been used to analyse the LBC1936's cognitive functioning at age 70 in previous chapters. In this study they were used to explore differences between the groups on the Physical Fitness domain. Results showed significant differences for *g* and speed, with the High Physical Wellbeing group scoring higher on both. Table 5.20 shows the results.

A logistic regression was run to find out whether any of the cognitive measures were predicting group membership. Results showed that for every unit increase in *g,* the odds of belonging to the High Physical Wellbeing group were 2.28, and for every unit increase in Memory performance the odds of belonging to the High Physical Wellbeing group were 0.75. Table 5.21 shows the results.

5.3.5 Social measures

Quality of life is a predictor of illness, disease and health outcomes in older adults (O'Boyle, 1997). This concept is highly associated with measures of emotional and psychological wellbeing, physical functioning, and social relationships (Williamson, Shaffer & Parmelee, 2000; Wood, Reyes-Alvarez, Maraj, Metoyer, Welsch, 1999). Studies (DiPietro, 2001; Rejeski & Mihalko, 2001) show that individuals with a higher quality of life, higher emotional stability, and good physical functioning are in better health and suffer from less disease.

In this study, three variables relating to psychosocial wellbeing, namely Physical Function, Quality of Life (QOL), and Emotional Wellbeing were used to differentiate between the 2 groups. These variables have already been used to analyse the LBC1936's psychosocial wellbeing at age 70 (Chapter 4). Results showed significant differences for Physical Function, Quality of Life, and Emotional Wellbeing, with the High Physical Wellbeing group showing higher scores in all variables. Table 5.22 shows the results.

Results from the logistic regression showed, that for every unit increase in Physical Functioning and Quality of Life, the odds of belonging to the High Physical Wellbeing group were 1.63 and 1.68 respectively. Table 5.23 shows the results.

5.4 Summary of results

Two groups of individuals with differing scores on Physical Fitness at age 70 were discovered in the LBC1936. These were assessed on levels of Physical Fitness, Lack of Inflammation and Lack of Morbidity. Although the 2 groups showed similar means on Lack of Inflammation, making the variable uninformative, opposing patterns were present for scores on Physical Fitness and Lack of Morbidity. Whereas one group was physically fit and relatively morbidity-free, thus labelled the High Physical Wellbeing group, the other group was physically unfit and high on morbidity, the Low Physical Wellbeing group.

Descriptive analyses were carried out to discover how the groups differed from each other on other variables relating to demographic, personality, health, cognitive, and psychosocial measures. Significant differences were found on a number of variables with the High Physical Wellbeing group scoring higher on age-11 IQ, the NART, total number of years in formal education, social class, higher scores on Extraversion, Agreeableness, Conscientiousness, *g*, Speed, Physical Function, Quality of Life, and Emotional Wellbeing; and the Low Physical Wellbeing group showing higher scores on the Neuroticism trait, a higher BMI, and a higher number of current smokers.

The NART, Neuroticism, BMI, smoking status, *g*, Physical Function, and Quality of Life also predicated group membership, with a higher likelihood of belonging to the High Physical Wellbeing group if NART scores are high, neuroticism is low, BMI is low, the person is a non-smoker, has high *g,* high Physical Function, and a high Quality of Life.

5.5 Final conclusions

The primary aim of this study was to identify potential profiles of physical wellbeing among 70-year-old individuals. Measures representing this domain included Physical Fitness, Inflammation, and Morbidity. These components were entered into a latent class analysis and 2 groups of individuals were revealed, the High Physical Wellbeing and the Low Physical Wellbeing groups. Results supported a dimensional dataset with the majority of individuals showing High Physical Wellbeing, and a smaller proportion showing Low Physical Wellbeing. Despite this difference, both groups showed similar scores on Inflammation, which means that this variable was not meaningful in this study. Differences amongst the groups were present on measures representing demographics, prior cognitive ability, personality, general health, cognitive function, and psychosocial wellbeing. Results from the external variables showed that most factors contributing to poor health in the Low Physical Wellbeing group are modifiable.

Table 5.1

Means of Physical Fitness for total participants, males and females separately (SDs in parentheses).

Physical Fitness	Total participants n = 1076	Males n = 543	Females n = 533
Grip Strength	28.82 (10.14)	36.57 (7.42)	20.97 (5.35)
FEV_1	2.36 (.69)	2.77 (.62)	1.94 (.46)
Gait speed	1.66 (.40)	1.76 (.40)	1.56 (.38)

Note. FEV_1 = Forced expiratory volume in 1 second.

Table 5.2.

Correlation coefficients for the Physical Fitness variables.

		1.	2.	3.
1.	Grip strength	-		
2.	FEV_1	.32**	-	
3.	Gait speed	.23**	.27**	-

Note. FEV_1 = Forced expiratory volume in 1 second. ** Correlation is significant at $p < .01$ (Pearson's r, 2 tailed), no adjustment for multiple testing.

Table 5.3.

Component loadings for the first unrotated principal components of the three variables reflecting Physical Fitness.

Variables	Loadings
Grip strength	.72
FEV_1	.75
Gait speed	.68

Note. FEV_1 = Forced expiratory volume in 1 second.

Table 5.4.

Means of Inflammation for total participants, males and females (SDs in parentheses).

Inflammation	Total participants (n = 1039)	Males (n = 517)	Females (n = 522)
CRP	5.26 (6.68)	4.97 (7.38)	5.55 (5.90)
Neutrophil count	4.44 (1.56)	4.33 (1.56)	4.55(1.56)
Fibrinogen	3.28 (.64)	3.34 (.63)	3.21 (.64)

Note. CRP = C-Reactive Protein

Table 5.5.

Correlation coefficients for the Inflammation variables.

	Inflammation	1	2	3
1.	CRP	-		
2.	Neutrophil count	.35**	-	
3.	Fibrinogen	.48**	.31**	-

Note. CRP = C-Reactive Protein. ** Correlation is significant at $p < .01$ (Pearson's r, 2 tailed) without adjustment for multiple testing.

Table 5.6.

Component loadings for the first unrotated principal components of the three variables reflecting Inflammation.

Variables	Loadings
CRP	.46
Fibrinogen	.45
Neutrophil count	.39

Note. CRP = C-Reactive protein.

Table 5.7.

Means of morbidity for total subjects, males and females (SDs in parentheses).

Morbidity	Total subjects n = 1091	Males n = 548	Females n = 543
Medical conditions	2.9 (1.7)	2.9 (1.6)	3.0 (1.6)
Medications	3.0 (2.5)	3.1 (2.5)	2.9 (2.5)

Table 5.8.

Correlation coefficients for the Physical Fitness components.

		1.	2.	3.
1.	Physical Fitness	-		
2.	Lack of Inflammation	-.02	-	
3.	Lack of Morbidity	.29**	.00	-

Note. ** Correlation significant at $p < .01$ (2-tailed), with no adjustment for multiple testing.

Table 5.9.

Model information criteria for each of the four, five and six class solutions.

Class-solution	AIC	BIC	Adjusted BIC
Two	8891.7	8941.6	8909.9
Three	8882.7	8952.6	8908.2
Four	8864.2	8954.1	8897.0
Five	8865.3	8975.2	8905.3

Note. AIC = Akaike information criterion. BIC = Bayesian information criterion. Adjusted BIC = (n* = (n* = (n + 2) / 24).

Table 5.10.

Probability of falling into a latent class according to physical measures in the Lothian Birth Cohort 1936.

Class	N	Probability of class 1 membership	Probability of class 2 membership
1	291	0.86	0.14
2	800	0.07	0.93

Table 5.11

Means of physical measures (standard deviations in parentheses) and significance values for each of the latent groups of the Lothian Birth Cohort 1936.

Group	N (%)	Physical Fitness	Lack of Inflammation	Lack of Morbidity
1	291 (26.7)	-.72 (1.0)	-.01 (1.0)	-1.3 (0.6)
2	757 (73.3)	.26 (0.9)	.00 (1.0)	.47 (0.6)
df		1037	1037	1089
t		-16.01	-.14	-41.05
p		.001	.892	.001

Table 5.12

Raw mean, standard deviations (SDs) and significance values for Age-11 IQ, NART, and years of formal education for the 2 groups in the Lothian Birth Cohort 1936.

Variables	Low Physical Wellbeing		High Physical Wellbeing				
	Mean	SD	Mean	SD	df	t	*p*
Age 11 IQ	96.7	16.6	101.2	14.2	1026	-4.2	.001
NART	32.3	8.4	35.3	7.9	1087	-5.6	.001
Years of education	10.5	1.0	10.8	1.2	1089	-4.1	.001

Note. NART = National Adult Reading Test.

Table 5.13

Proportions, percentages and significance values for sex, marital status, and living status in the Lothian Birth Cohort 1936.

Variables	Low Physical Wellbeing		High Physical Wellbeing				
	N	%	N	%	df	X^2	p
Sex							
Males	155	53.3	393	49.1			
Females	136	46.7	407	50.9			
N	291	100	800	100	1	1.46	.227
Marital Status							
Married	208	71.5	570	71.3			
Single	18	6.2	47	5.9			
Divorced	23	7.9	61	7.6			
Cohabiting	2	0.7	15	1.9			
Widowed	39	13.4	107	13.4			
Other	1	0.3	0	0			
N	291	100	800	100	5	4.74	.449
Living Status							
Alone	72	24.7	194	24.3			
Not alone	219	75.3	606	75.8			
N	291	100	800	100	1	.03	.867

Table 5.14

Odds ratios (OR) for group membership for the demographic and prior cognitive ability measures in the Lothian Birth Cohort 1936, with 95% confidence intervals.

Variable	OR	95% CI	
	High (vs. Low) Wellbeing	Lower	Upper
Sex	1.25	0.92	1.68
Age 11 IQ	1.00	1.00	1.02
NART	1.04**	1.01	1.07
Years of Educ	1.09	0.92	1.28
Marital status	1.01	0.86	1.18
Living status	1.11	0.66	1.88
Social class	1.00	0.83	1.20

Note. OR = Odds Ratio. CI = confidence interval. NART = National Adult Reading Test. ** $p < .01$. p-values have been adjusted for multiple testing using Bonferroni correction.

Table 5.15

Raw means, standard deviations (SDs), and significance values for neuroticism, extraversion, openness, agreeableness, and conscientiousness traits in the 2 groups in the Lothian Birth Cohort 1936.

Variables	Low Physical Wellbeing		High Physical Wellbeing				
	Mean	SD	Mean	SD	df	t	*p*
Neuroticism	18.9	7.9	16.5	7.4	952	4.4	.001
Extraversion	26.2	6.3	27.2	5.8	941	-2.3	.024
Openness	25.4	6.0	26.3	5.7	945	-2.0	.046
Agreeableness	32.5	5.4	33.8	5.2	952	-3.1	.002
Conscientiousness	33.6	6.4	35.0	5.8	945	-3.1	.002

Note. No adjustment for multiple testing.

Table 5.16

Odd ratios (OR) for group membership for the personality measures of Lothian Birth Cohort 1936 participants, with 95% confidence interval (CI)

Variable	OR	95% CI	
	High (vs Low) Wellbeing	Lower	Upper
Neuroticism	0.96**	0.94	0.98
Extraversion	0.99	0.97	1.02
Openness	1.02	0.99	1.05
Agreeableness	1.03	1.00	1.06
Conscientiousness	1.02	0.99	1.05

Note. OR = Odds Ratio. CI = Confidence Interval. ** $p < .01$. *p*-values have been adjusted for multiple testing using Bonferroni correction.

Table 5.17

Raw means, standard deviations (SDs) and significance values for BMI and total units of alcohol consumed per week for each of the 2 groups in the Lothian Birth Cohort 1936.

Variables	Low Physical Wellbeing		High Physical Wellbeing				
	Mean	SD	Mean	SD	df	t	*p*
BMI	29.3	4.9	27.2	4.0	1087	7.1	.001
Units of alcohol/week	10.8	16.9	10.4	13.1	1089	0.4	.686

Note. BMI = Body Mass Index. No adjustment of significance levels for multiple testing.

Table 5.18

Proportions, percentages, and significance values for APOEe4 allele and smoking status in the 2 groups in the Lothian Birth Cohort 1936.

Variables	Low Physical Wellbeing		High Physical Wellbeing				
	N	%	N	%	df	X^2	p
APOE e4							
Not present	202	72.4	520	69.4			
Present	77	27.4	229	30.6			
N	279	100	749	100	1	.861	.353
Smoking category							
Never smoked	94	32.3	380	47.5			
Ex-smoker	150	51.5	321	40.2			
Current smoker	47	16.2	99	12.4			
N	291	100	800	100	20.1	2	.000

Note. APOEe4 = Apolipoprotein E allele 4.

Table 5.19

Odds ratios (ORs) for group membership for health measures of the Lothian Birth Cohort 1936 participants with 95% confidence intervals.

Variable	OR High (vs. Low) Wellbeing	95% CI Lower	Upper
BMI	0.90***	0.87	0.93
APOE e4	1.12	0.82	1.54
Units alcohol/week	1.00	0.99	1.10
Smoking category, smoker	0.64***	0.52	0.78

Note. p-values have been adjusted for multiple testing using Bonferroni correction. OR = Odds Ratio. CI = Confidence Interval. BMI = Body Mass Index. APOE e4 = Apolipoprotein E allele 4 *** $p < .001$.

Table 5.20

Raw means, standard deviations (SDs) and significance values for cognitive ability for each of the 2 group in the Lothian Birth Cohort 1936.

Variables	Low Physical Wellbeing		High Physical Wellbeing				
	Mean	SD	Mean	SD	df	t	*p*
g	-0.26	0.7	0.10	0.7	1069	-7.4	.000
Memory	-0.02	0.8	0.02	0.8	1046	-0.9	.358
Speed	-0.06	0.6	0.04	0.5	1037	-2.6	.008

Note. g = general cognitive ability. No adjustment of significance levels for multiple testing

Table 5.21

Odd ratios (ORs) for group membership for physical wellbeing of the Lothian Birth Cohort 1936, participants with 95% confidence intervals (CIs).

Variable	OR	95% CI	
	High (vs Low) Wellbeing	Lower	Upper
g	2.28***	1.79	2.91
Memory	0.75**	0.61	0.93
Speed	1.20	0.92	1.57

Note. p-values have been adjusted for multiple testing using Bonferroni correction. OR = Odds Ratio. CI = Confidence Interval. *** $p < .001$. ** $p < .01$

Table 5.22

Raw means, standard deviations (SDs) and significance values for social measures for each of the 2 groups in the Lothian Birth Cohort 1936.

Variables	Low Wellbeing	Physical	High Wellbeing	Physical			
	Mean	SD	Mean	SD	df	t	*p*
Physical function	-0.45	1.1	0.15	0.9	950	-8.42	.000
QOL	-.053	1.2	0.18	0.9	956	-10.18	.000
Emotional wellbeing	-0.37	1.1	0.13	0.9	1083	-7.45	.000

Note. QOL = Quality of Life. No adjustment of significance levels for multiple testing.

Table 5.23

Odd ratios (ORs) for group membership for Physical Fitness of the Lothian Birth Cohort 1936 participants with 95% confidence intervals (CIs).

Variable	OR	95% CI	
	High (vs Low) Wellbeing	Lower	Upper
Physical function	1.63***	1.37	1.94
QOL	1.68***	1.38	2.05
Emotional wellbeing	1.12	0.93	1.35

Note. QOL = quality of life. *** $p < .001$. p-values have been adjusted for multiple testing using Bonferroni correction.

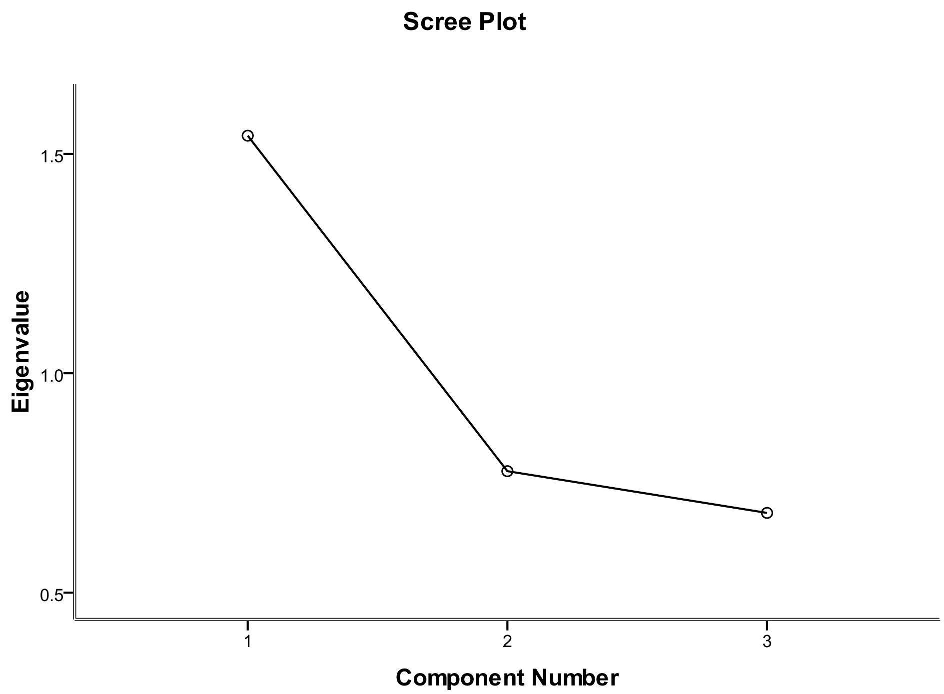


Figure 5.1. The scree plot for Physical Fitness displaying inflexions that would justify retaining one component.

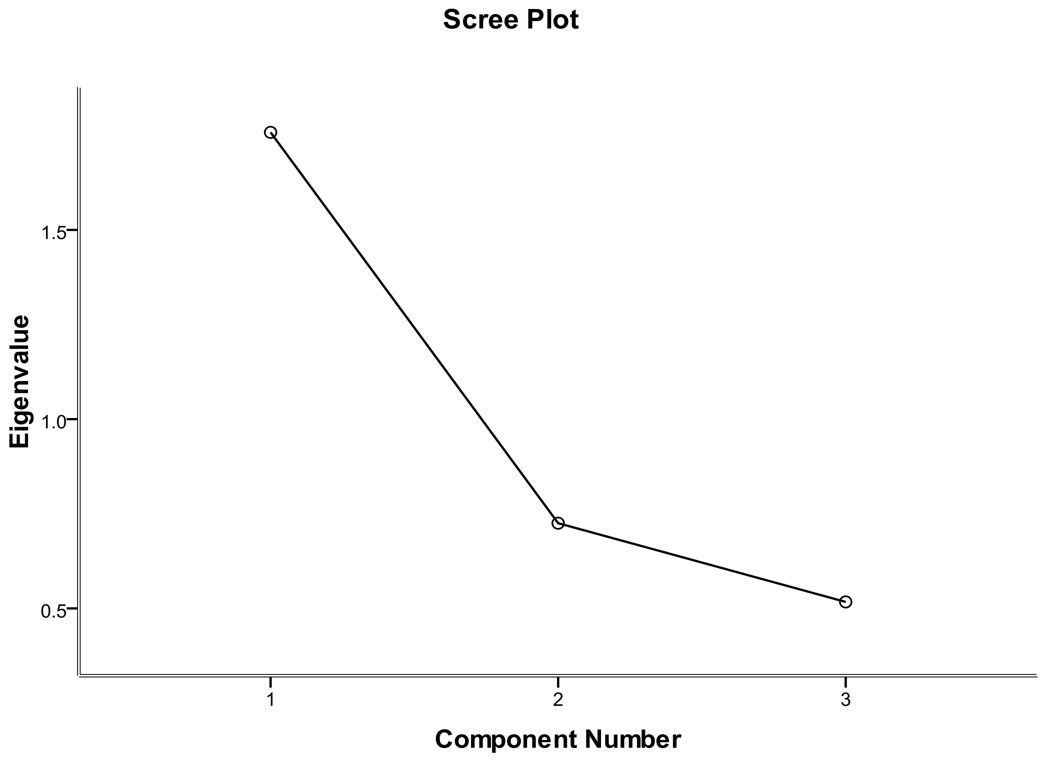


Figure 5.2. The scree plot for Inflammation displaying inflexions that would justify retaining one component.

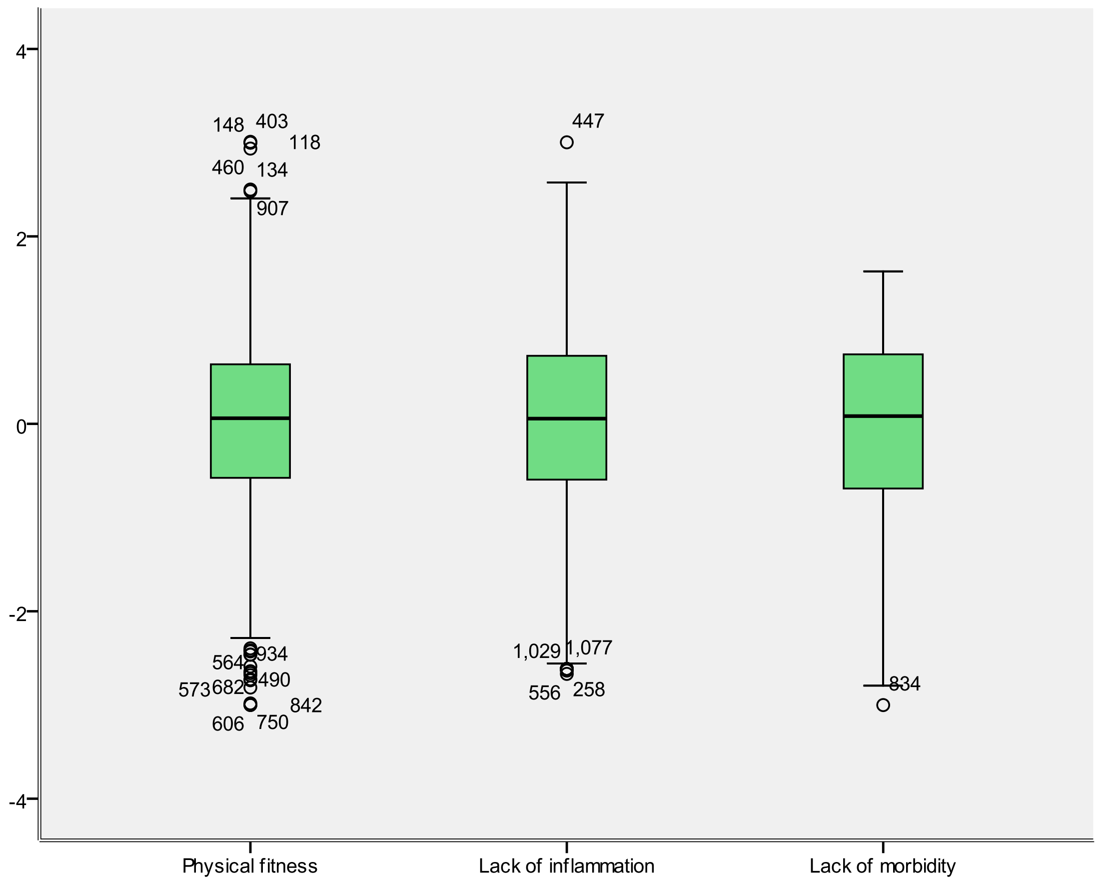


Figure 5.3. The boxplots of the physical components retained from PCA with winsorised scores.

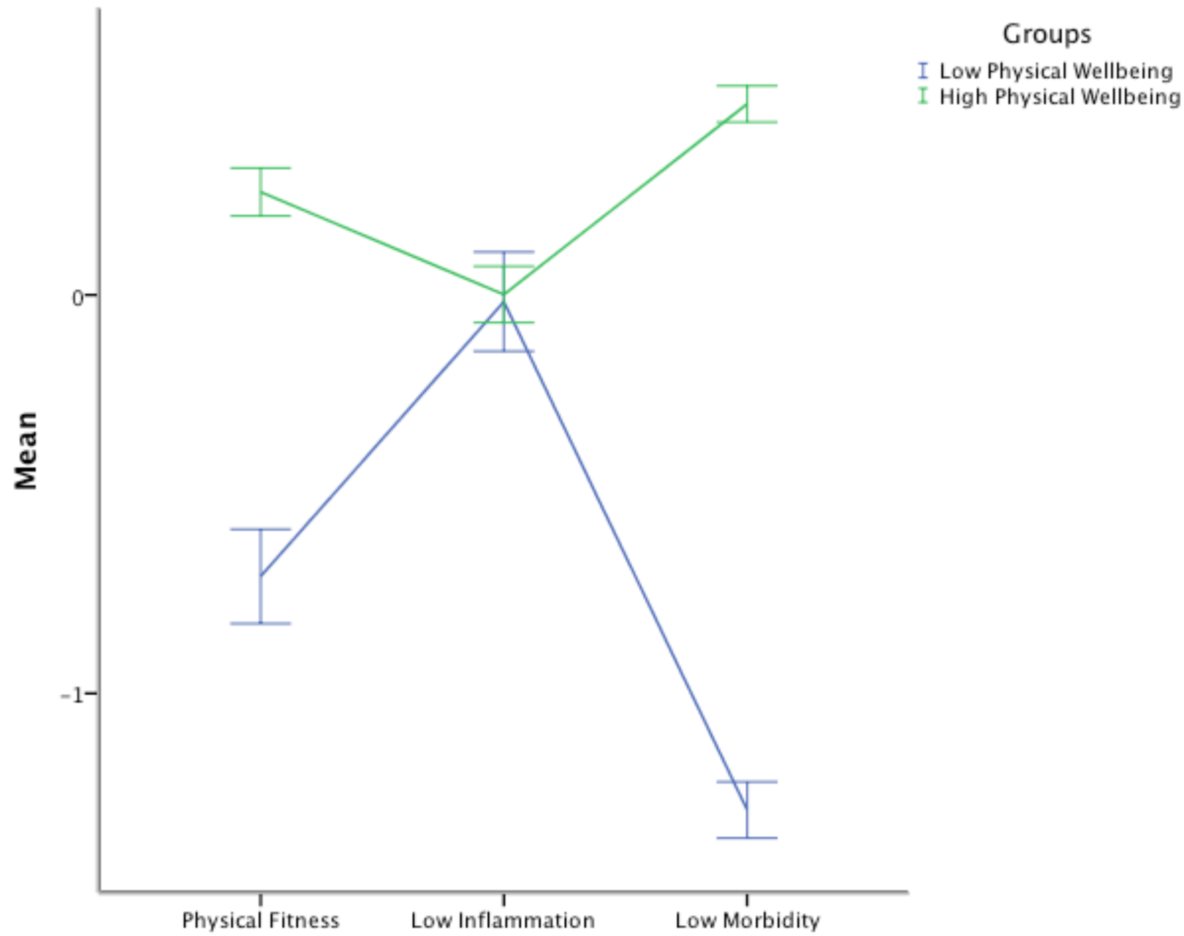
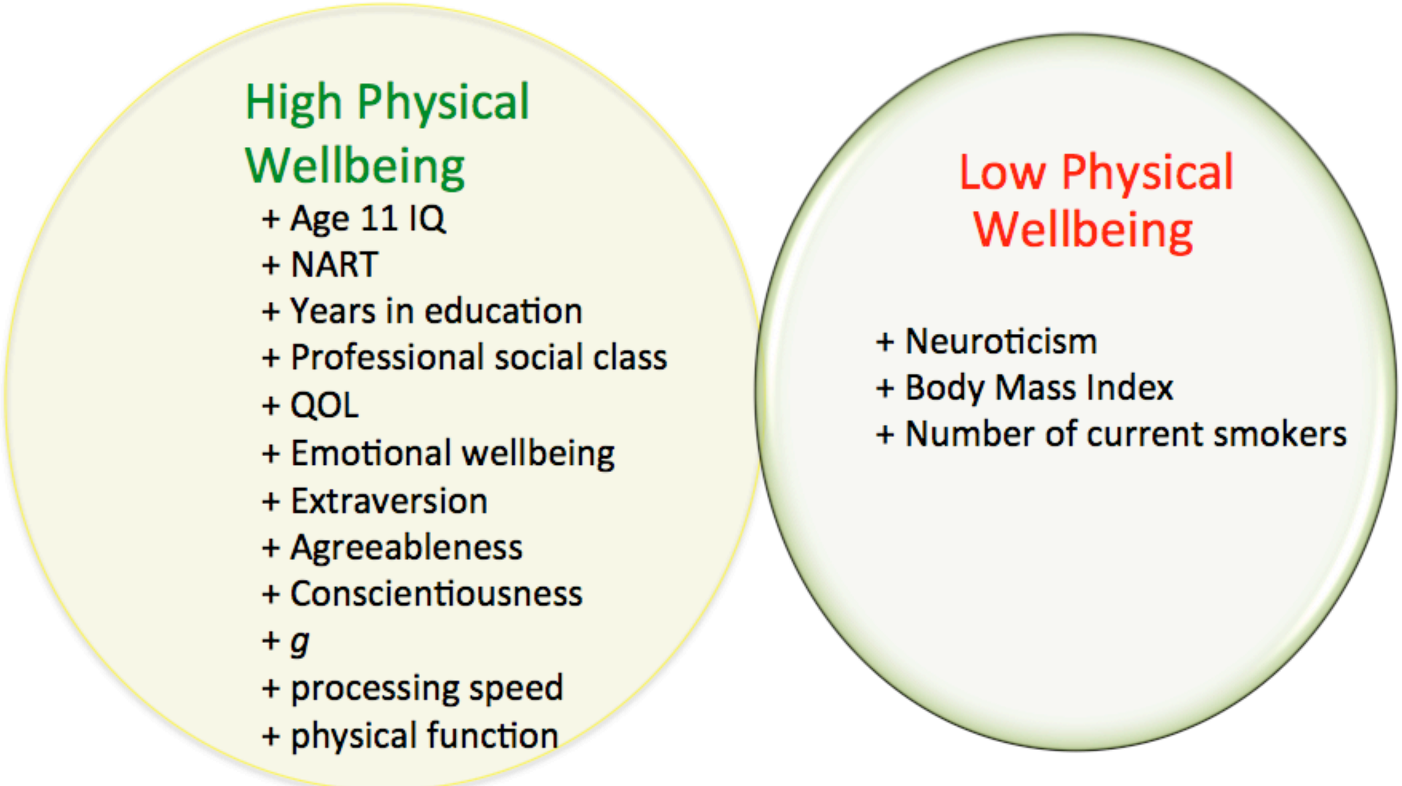


Figure 5.4. The groups' mean scores on each of the physical components, namely Physical Fitness, Lack of Inflammation, and Lack of Morbidity, with 95% confidence intervals, as generated from latent class analysis for the Lothian Birth Cohort 1936 sample.



Note. NART - National Adult Reading Test
QOL - Quality of life
g - General cognitive ability

Figure 5.5. Venn diagram illustrating the differences characterising the groups.

6. The Three Main Wellbeing Domains

Wellbeing in old age is multidimensional (Crimmins, 2004). Areas relating to wellbeing such as health, cognition, physical fitness and psychosocial status affect individuals heterogeneously due to the variability and interdependence of the unfolding of these domains throughout the years (Lafortune, Beland, Bergmen at al., 2009). In the previous chapters I derived three principal components for each of the cognitive, the psychosocial, and the physical domains. I then used latent class analysis (LCA) to group and classify individuals in the Lothian Birth Cohort 1936 (LBC1936) according to their scores on these components. To adopt a more multidimensional approach in this chapter, I used all the components from each domain that I extracted previously, together, i.e. each of the nine components of wellbeing identified in previous chapters; these included General Cognitive Ability (*g*), Memory, and Speed for Cognitive Ability; Quality of Life (QOL), Emotional Wellbeing, and Physical Function for Psychosocial Wellbeing; and Physical Fitness, Lack of Inflammation and Lack of Morbidity for Physical Fitness, with the aim of identifying and classing homogenous groups of individuals according to their wellbeing as measured by variables relating to cognitive ability, physical fitness, and psychosocial wellbeing.

Thus the aim of this chapter was to explore wellbeing within the LBC1936 on a holistic level, and to find out whether groups of individuals could be observed by integrating these domains of cognitive, physical and psychosocial function in old age, and if so, to identify the variables associated with them. I did this by applying LCA to LBC1936 participants' scores from the nine variables constituting the three domains.

6.1 The Nine Components of the Three Domains of Wellbeing

The nine components: *g*, Memory, and Speed, QOL, Emotional Wellbeing, and Physical Function, and Physical Fitness, Lack of Inflammation and Lack of Morbidity; that had been derived in earlier chapters from principal components analysis (PCA) had already been tested for normality as described in previous chapters. Thus, components that showed outliers had already been winsorised. Any score that fell above or below three standard deviations (SDs) was adjusted to either -3 or +3 SDs, depending on whether the outlier was below or above the mean.

First, Pearson's correlation coefficients were calculated. Most of the variables showed positive associations in which higher scores reflected better wellbeing. These can be seen in Table 6.1. The strongest correlations were between Emotional Wellbeing and QOL (.57, $p < .01$); Speed and *g* (.46, $p < .01$), and between Lack of Morbidity and QOL (.32, $p < .01$). The majority of the rest of the associations were both within and between major domains of Cognitive Ability, Psychosocial Wellbeing, and Physical Fitness. These associations were also meaningful in that better scores on the cognitive components were associated with higher scores on variables reflecting psychosocial and physical fitness domains. Lack of Inflammation was the only variable that did not show any significant associations with any of the variables, apart from a low but negative correlation with QOL. The lack of associations with this variable was not surprising since it also failed to give significant results in previous chapters. Other pairs of variables that did not correlate significantly included Physical Function and Speed, and Physical Function and Memory. Although the cognitive variables in this study did not correlate with Physical Function, they correlated highly with Physical Fitness, which is a component derived from variables representing Grip Strength, Gait speed, and Forced Expiratory Volume in one second (FEV_1), which are more reflective of body strength and speed, than the Physical Function variables, which are derived from mean scores on Activities of Daily Living (ADLs), Level of Physical Intensity and Number of Days Active per Month. Other variables that did not correlate significantly included

Emotional Wellbeing and Speed, and Lack of Morbidity and Memory. This perhaps showed that cognitive function was not always associated with specific variables relating to psychosocial wellbeing and physical fitness.

6.2 Formation of groups using latent class analysis

In previous chapters, each of these domains' components was submitted to LCA separately. In this chapter all components were submitted together. Thus, participants' scores on *g,* Memory, Speed, QOL, Emotional Wellbeing, Physical Activity, Physical Fitness, Lack of Inflammation, and Lack of Morbidity were submitted to LCA. Two-, three-, four-, five-, six-, and seven- group solutions were defined in the latent class models and run using MPlus (Muthen & Muthen, 2004). In previous chapters I also ran models between two- and seven- group solutions since there seemed to be an optimal solution in this range. Participants were assigned to the group to which they had the highest probability of belonging according to their responses on *g*, Memory, Speed, QOL, Emotional Wellbeing, Physical Activity, Physical Fitness, Lack of Inflammation and Lack of Morbidity, as indicated by LCA. The results from these solutions were compared using the Akaike information criterion (AIC), the Bayesian information criterion (BIC), and the adjusted BIC. Entropy (ENT), which is a measure used to indicate how well the variables predict group membership (Celeux & Soromenho, 1996), was also used. In this context, entropy is defined on a 0 to 1 range with values closer to 1 indicating a higher degree of certainty in membership classification, and values closer to 0 indicating lower certainty. Thus the closer to 1 the average group probability is the better defined the groups are. As before, solutions that included groups containing less than 5% of the population were avoided unless they had distinctive qualities setting them aside from the rest of the groups, because groups of this size are more likely to have resulted from capitalisation on chance sample characteristics. The most parsimonious solution was also sought. 20 random starts were used in the initial stage and 10 optimisations in the final stage to get appropriate model convergence and to be confident of a robust solution. Although all fit statistics seemed to keep improving with every added group, the group patterns across variables seemed to be getting less parsimonious, with more groups showing similar patterns that could be combined to form more informative groups. This is typical of situations where the data are continuous - although the fit improves with added groups, parsimony decreases, and the chosen group solution is ultimately a matter of the researcher's informed opinion (Johnson et al., 2007). LCA has been developed to recover qualitative and categorical outcomes (McCuthcheon, 1987); however, it has also been used on continuous data (McLachlan & Peel, 2000), in which the breakdown of natural categories is less likely since the underlying data are dimensional. As in this study, the outcome would be discontinuous since there will have to be some breakpoints to generate groups. However, breaking up a continuum of scores and creating groups out of dimensional patterns of scores can be helpful to summarise mean patterns of scores of a number of individuals (Nagin & Tremblay, 2005). Therefore, as Nagin and Tremblay (2005) have done before, in this study groups were considered as a useful statistically-derived outcome to be used for further description and exploration, since it was acknowledged that it is highly likely that there would not be any natural groups on any of the variables of interest. Thus, the analyses are intended to help in developing a descriptive summary of the patterns of wellbeing across the LBC1936 cohort.

The AIC, the BIC, and the adjusted BIC, suggested a 4-or 5-group solution. Model-fit statistics can be seen in Table 6.2, and Figure 6.1 displays these results. The ENT had a maximum of 0.826 at 2 groups, and a minimum of 0.745 at 7 groups. The ENTs for the 3-, 4-, 6-, and 5-group solutions were 0.746, 0.771, 0.759, and 0.769. The 2-group solution showed the best discrimination amongst the groups, whereas the rest averaged at an ENT of 0.752. Tables 6.3 – 6.8 detail the group sizes, percentages and probabilities for each of the 2-, 3-, 4-, 5-, 6-, and 7- group solutions, and Figures 6.2 – 6.7 illustrate these results. The figures show that there consistently is a group that seems to be doing relatively well on all variables, whilst other groups score well on some variables but poorly on others. As can be seen in Tables 6.3 and 6.4, the 2-group solution seemed to have grouped the cohort into a majority high-wellbeing and an approximately 20% low-wellbeing group; however, this model missed out on the interaction that appeared in the 3-group solution, in which two low performing groups showed opposing scores on Cognitive Functioning, and Psychosocial and Physical Wellbeing. The groups were also more equally divided; the high scoring group constituted 65.3 % of the population, and the two low-scoring groups together made up 34.8%. For most likely group membership, the probabilities in the 3-group solution ranged from 0.81 to 0.91, indicating reasonably clear group membership for most participants. Thus, the 3-group solution model seemed to have identified a potentially important difference among otherwise generally low-scoring individuals. Moreover, the 4-group solution included a subgroup with only 15 participants, which is only 1.4% of the sample. Although this small subgroup had an interesting pattern of scores (high Psychosocial Wellbeing, above average Physical Fitness, and very low Cognitive function), it contained a very small proportion of the sample, and it was unlikely to be robust. This same pattern of subgroups comprising less than 5% of the population also occurred in the 5, 6, and 7 group-solutions. Patterns of results from 4 groups or more were neatly summarised in the 3-group model, but were not captured in the 2-group model. Thus since models with 4 or more group solutions contained less than 5% of the population, and the model with the 2- group solution did not capture the interaction in the 3- group solution I judged that the model containing three groups of people was the most parsimonious solution with substantial numbers of participants per group, and thus most likely to provide a meaningful description of the patterns of association in the data. The 3-group solution was thus selected for further analysis.

6.2.1 Testing the three-group model

To investigate whether the 3-group solution was the optimal model, some further tests were run. Firstly, the whole sample was split into two random groups. I ran 2-, 3-, 4-, and 5- model solutions on each half in LCA. The generated output containing model information criteria, group sizes and percentages of each of the two sub-samples can be seen in Tables 6.9, 6.10, and 6.11. The results of the two sub-samples were very similar to each other and to the results from the whole sample; i.e. the information criteria improved as the numbers of groups increased, and increasing number of groups-solutions (< 4) tended to contain groups making up less than 5% of the population. For this reason no further group solutions were sought, and the 3-group model was further investigated in each sub-sample. Figures 6.8 and 6.9 show that the patterns of each of the groups in these sub-samples contained a group that scored highly across all variables, a group that scored poorly on Cognitive Ability but better on the rest of the variables, and a group that scored poorly on variables relating to Psychosocial Wellbeing and Physical Fitness but that showed better scores on Cognitive Ability. The similarity in the pattern of scores in these two sub-samples helped to confirm further the option of three-group model in the whole sample.

To test the accuracy of the group assignments of the 3-group model I assessed the degree to which it was replicable. I did this by testing whether the groups identified in the first sub-sample could be reproduced in the other half. Thus, one of the sub-sample's participants was considered to have known group membership based on results from the 3-group model. This was used to predict membership for the other half of the participants by testing whether the new predicted membership differed from that originally assigned. The criteria used to form the 3-group solution in the first sub-sample were thus used to assign group membership in the second sub-sample, and these assignments were compared with those from the 3-group solution generated in this sample. Using chi-square, the differences between original group membership results and predicted membership results were tested; a significant difference between original and predicted memberships χ^2 (4) = 473.6, p <. 001 was present. Although this result showed that significant differences were present between the original and predicted group membership results, ENT was high in both sub-samples: 0.891 and 0.887, which showed that groupings were relatively high. The total number of participants belonging to their assigned group at a probability of 0.90 or higher can be seen in Table 6.12. As can be seen in the Table, the majority of cases have at least 0.90 probability of belonging to their respective group, although this was not the case for Group 1. Overall similarity but absence of strict replication is consistent with a lack of clear separation between classes and probably indicates underlying dimensions rather than naturally occurring categories.

6.2.2 Profiles of the latent groups

A 3-group model of wellbeing membership across nine variables was eventually selected to represent the LBC1936 sample. Results from this model showed differences amongst the groups in several ways across areas of Cognitive Ability, Psychosocial Wellbeing, and Physical Fitness. Here the profile of each of these groups is described in some detail.

The largest group, Group 3 (n = 712) had relatively high scores across all variables. Group 1 (n = 221) had low scores (~ -1SD) across the Cognitive Ability variables but average scores on variables relating to Psychosocial Wellbeing and Physical Fitness, whilst Group 2 (n = 158) had poor scores (~ -1SD) on Psychosocial Wellbeing and Physical Fitness, and just below average scores on variables reflecting Cognitive Function. The first two groups deviated from the overall pattern (as depicted by Group 3), and also indicated the presence of heterogeneous groups within the sample; i.e. the pattern of results displayed for Groups 1 and 2 showed that, although individuals belonging to these groups had low scores relative to Group 3, they seemed to have relatively high scores in some domains but not others. For this reason, these groups were simply labelled as Low Bio-psychosocial and Low Cognition. The remaining group was labelled as High Wellbeing because it had relatively high scores on all components. This was also the largest group, which suggested that the majority of the sample was not showing poor scores on all domains of wellbeing in old age. The means of each of the groups and their differences on these variables can be seen in Table 6.13; and a display of the means can be seen in Figure 6.3.

6.3 Formation of the Domains of Wellbeing

As the previous section illustrated, individuals were clearly grouped either into groups scoring high on all variables, scoring low on variables relating to Cognition or scoring low on variables relating to Bio-psychosocial Wellbeing. The aim of this section was to summarise the three derived groups according to their scores on the following variables - *g*, Memory, Speed, QOL, Emotional Wellbeing, Physical Function, Physical Fitness, Lack of Inflammation and Lack of Morbidity - by combining them into components using PCA to provide a neat summary of the differences between the groups more clearly, thus making existing differences more apparent. The aim of this was purely for descriptive and for illustrative purposes, since formation of, and differences amongst groups have already been achieved in previous sections, and new results were not being sought.

The nine variables representing Cognitive Ability, Psychosocial Wellbeing, and Physical Fitness mentioned above were all submitted into one PCA to find out how they grouped together. By doing this, the nine variables representing various areas of wellbeing would still be present, but in a more concise format and would still be reflecting the same results obtained previously using LCA. PCA on the nine variables using both Varimax and Oblimin rotation was applied, the latter being applied to see how results may have differed when the variables were allowed to correlate. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was .68, which is above the acceptable limit of .5 (Field, 2009). Barlett's test of sphericity χ^2 (36) = 982.34, $p < .001$ indicated that correlations among the subtests were sufficiently large for PCA. An initial analysis was run to obtain eigenvalues for the components in the data. There were three components that had eigenvalues over Kaiser's criterion of 1. In the Varimax rotation these explained 24.4%, 17.7% and 11.9% of the total variance; whereas in the Oblimin rotation these explained 27.1%, 15.1%, and 11.4% of the total variance. However, examination of the scree plot showed inflexions that would justify retaining only two components. This was the same in both solutions, and can be seen in Figure 6.10. The component matrix also showed that the third component was unnecessary since none of the variables loaded on it. Thus another PCA was run using a two-component solution again with both varimax and oblimin rotation. The two components explained 25% and 42.1% of the total variance in the varimax rotation, and 27.1% and 42.2% of the total variance in the oblimin rotation. Table 6.14 shows the component loadings on each of the two components of both the varimax and the oblimin rotations. Lack of Inflammation had a low communality in both solutions. As can be seen in the table, both solutions provided similar results. Furthermore, QOL, Emotional Wellbeing, Physical Fitness, Lack of Morbidity, and Physical Function loaded onto one component, whereas *g,* Memory, Speed and Low Inflammation loaded on another. These were thus labelled the Bio-Psychosocial component and the Cognitive component.

Once the PCAs was run and the components extracted, a figure displaying the factor score means of the three groups using varimax regression scores, was plotted. As can be seen in Figure 6.11, the trend from Figure 6.1, which has nine variables could be summed up nicely into two major components representing the domains of Bio-psychosocial Wellbeing and Cognitive Ability. The grouping of variables into two major components made the differences among the groups more apparent. Table 6.15 shows the means and differences amongst the groups on these components can be seen in Table 6.15.

An interesting characteristic distinguishing the Low Cognition and the Low Bio-Psychosocial group from the High Wellbeing group was the reversed pattern of cognitive ability, and psychosocial and physical wellbeing in the Low Bio-psychosocial and Low Cognition groups. This was worth exploring, especially to find out what distinguished between these groups. In the next section, a number of variables that distinguished amongst the Groups were identified and used as descriptors of the three groups. The aim was to find out what was associated with group membership, and in what ways the groups differed from each other, especially the High Wellbeing group from the Low Bio-psychosocial and Low Cognition groups.

6.4 Descriptors and predictors of the Domains of Wellbeing at age 70

The majority of the participants fell into the High Wellbeing group (n = 712); however, a substantial number of cases fell into the other two groups, the Low Bio-psychosocial (n = 158) and the Low Cognition (n = 221) groups.

The aim of this section was to find out and describe how the three groups differed on variables relating to demographic measures, personality, and health. These variables were accordingly labelled as descriptors and predictors of the three-formed groups' Cognitive and Bio-Psychosocial wellbeing at age 70.

A thorough description of all the variables mentioned in this chapter can be found in Chapter 2, entitled *Methodology*. In all instances, analyses of variance (ANOVA) were first used to find out if significant differences were present amongst the groups on any of the variables. Post-hoc analysis for the significant findings from ANOVA using Tukey's Honestly Significant Difference (HSD) test comparisons was also carried out in order to find out which groups differed significantly from each other. Tukey's HSD test is a multiple-comparison statistical test used to discover which groups differ significantly from each other by comparing all pairs of means. This was followed by multinomial logistic regression (MLR) with the aim of predicting group membership. The High Wellbeing group was used as the baseline group in all MLR analyses run. The logistic regression *p*-values were also adjusted for multiple testing using the Bonferroni correction in all regression analyses in this chapter.

A Venn diagram illustrating the similarities and differences characterising the groups on the external variables can be seen in Figure 6.12.

6.4.1 Demographic measures and prior cognitive ability

Literature (Antonucci, Lansford & Akiyama, 2001; Starr, Deary, Lemmon & Whalley, 2000; Fried, Ettinger, Lind et al., 1994) highlights the associations between higher education, higher social class levels, higher IQ, and being married with greater levels of wellbeing in the elderly. In this study, the demographic measures used to describe the three groups included sex, age-11 IQ, the National Adult Reading Test (NART), total number of years in formal education, marital status, living status, and social class. These were included in the ANOVAs as dependent variables with group number as the independent variable.

Significant differences amongst the groups were found for sex; age-11 IQ, the NART, total number of years in formal education, marital status, living status, and social class. Tables 6.16 and 6.17 show the raw means and standard deviations along with ANOVA results of the continuous and categorical demographic variables for each of the 3 groups.

Post-hoc results using Tukey's HSD showed that the High Wellbeing group had significantly higher age-11 IQ, a higher NART score, more years in education, and a higher social class than the rest of the groups. The Low Cognition group, on the other hand had significantly lower scores on age-11 IQ, the NART, and years in education. However, there were no significant differences on total number of years in education and social class between the Low Bio-psychosocial and the Low Cognition groups. This result reflects the high correlations present among the dependent variables. These can be seen in Table 6.18.

The Low Bio-psychosocial group had the highest percentage of females (53.2%), widowed individuals (17.1%), and individuals who lived alone (31%). This may reflect the morbidity-mortality paradox (Kulminski, Culminskaya, Ukraintseva, et al., 2008) where females are likely to live longer but suffer from low quality of life, which seems to be a likely possibility in this group. On the other hand, there were significantly more males (57.9%) in the Low Cognition group, but it was the High Wellbeing group that had the highest percentage of individuals who were still married (75%), and the lowest percentage of divorced individuals (5.8%).

MLR analysis using the above-mentioned variables was then applied to explore if any of these were associated with group membership in the three groups. Results showed that individuals with higher age-11 IQs, higher NART scores, and more number of years in education were more likely to belong to the High Wellbeing group. These were congruent with results from the ANOVAs; however, unlike ANOVA results, sex, marital status, living status, and social class in the MLR did not distinguish amongst the groups. This may just be due to power differences between ANOVA and MLR tests, the former of which does not assume order for categorical variables. Table 6.19 shows the results.

6.4.2 Personality Measures

Many studies have been carried out investigating the role of personality in wellbeing. Neuroticism is widely studied due to its associations with reduced wellness and poor health (Friedman, Kern & Reynolds, 2010). On the other hand, traits of Extraversion, Agreeableness, and Conscientiousness are strongly and positively correlated with health and wellbeing affecting social competence, higher productivity, and lower mortality risk (Friedman, Kern & Reynolds, 2010). The NEO-PI-R inventory was used to study personality measures in this sample and to describe and distinguish amongst the 3 groups. Significant differences amongst the groups were found for Neuroticism, Extraversion, Agreeableness, Conscientiousness, and Openness, with the High Wellbeing group showing higher scores on all variables except for Neuroticism, on which they showed lower scores. Table 6.20 shows the raw means and standard deviations along with the ANOVA results of the three groups.

The High Wellbeing group had significantly higher scores on Extraversion, Conscientiousness, Agreeableness, and Openness, and significantly lower scores on Neuroticism than the rest of the groups. On the other hand, the Low Bio-psychosocial group had the opposite trend, with significantly lower scores on Extraversion, Agreeableness and Conscientiousness, and significantly higher scores on Neuroticism than the rest of the groups. The Low Cognition group, on the other hand had significantly lower levels on Openness than the rest of the groups. There were no differences between the Low Cognition and High Wellbeing groups on Neuroticism, Extraversion and Conscientiousness. Table 6.21 shows the results.

In summary, the High Wellbeing group had the highest scores on Extraversion, Openness, Agreeableness and Conscientiousness; and the lowest scores on Neuroticism. The Low Cognition group had the lowest scores in Openness. The Low Bio-psychosocial group had the highest levels of Neuroticism, and the lowest scores in Extraversion, Agreeableness and Conscientiousness.

MLR using these personality measures was applied to find out whether any of these were predicting class membership. Results showed Neuroticism, Extraversion, Openness, and Conscientiousness predicted group membership. Individuals in the Low Bio-psychosocial group were more likely to score higher on Neuroticism and less likely to score highly on Extraversion, Openness, or Conscientiousness; and individuals in the Low Cognition group were more likely to have high Neuroticism scores and less Openness than individuals in the High Wellbeing Group. Unlike results from the ANOVA, Agreeableness did not show any significant findings in MLR, which again may be due to the difference in the power of these tests. Table 6.22 shows the results.

6.4.3 Health measures

Physical fitness and health behaviours are related (Schmite, Kruse, & Kugler, 2007). In this study, units of alcohol consumed per week, body mass index (BMI), smoking category (smoker, non-smoker, ex-smoker), and presence/absence of *APOE* e4 allele were used to analyse and differentiate amongst the 3 groups. Significant differences were found for BMI and smoking behaviour, in which the Low Bio-psychosocial group showed a significantly higher BMI and a higher percentage of current smokers than the High Wellbeing group. Results can be seen in Tables 6.23, 6.24 and 6.25.

MLR using the mentioned health measures was used to find out whether any of these variables were predicting group differences. Results showed that individuals were more likely to belong to the High Wellbeing group if they had a lower BMI and had never smoked. Table 6.26 shows the results.

6.5 Discussion of results

The aims of this chapter were to explore whether individuals could be grouped according to their scores on 9 cognitive, physical, and psychosocial wellbeing measures at age 70, and to characterise any groups I found using LCA. Three groups showing high or mixed degrees of wellbeing in old age were identified. Two latent components, Cognitive Wellbeing and Bio-Psychosocial Wellbeing were also derived from the 9 wellbeing variables. This helped in describing the differences among the groups more clearly. Although results suggested that distinct subgroups of individuals did not exist in this dataset and that wellbeing across these domains was dimensional i.e. ranging from low to high scores across individuals, a majority scored consistently highly across all domains of cognitive, physical and psychosocial wellbeing (High Wellbeing), which was likely given the criteria and health screening that went into sample recruitment. Two other groups were identified. Individuals in one group seemed to have relatively good scores on cognitive measures, but poor scores on bio-psychosocial measures (Low Bio-Psychosocial), whilst individuals in another group seemed to have relatively good scores on bio-psychosocial markers, but poor scores on cognitive measures (Low Cognition). These three established groups served as a useful tool to describe wellbeing amongst 70-year olds in this cohort. Other studies that have also studied different profiles of wellbeing in old age (e.g., Gerstrof et al., 2006; Ko et al., 2007; Parslow, Lewis & Nay, 2011; Smith & Baltes, 1997) have concluded that wellbeing in this age group can be expressed in various forms and can still take place despite functional limitations in one domain.

A wide range of variables relating to demographics, early life cognition, personality, and health behaviour, were used to measure differences amongst the groups. Results supported literature on successful ageing in that individuals who have good levels of wellbeing also tend to have higher levels of education, better physical wellbeing, better health, and higher levels of survival (Smith and Baltes, 1997). Moreover, previous results (Batty, Deary & Gottfredson, 2007; Johnson, Corley, Starr & Deary, 2011) on the effects age-11 IQ seems to have on wellbeing in old age were also supported in this study, in that a higher score was associated with better wellbeing. Compared to other groups the High Wellbeing group had relatively high childhood IQ scores (effect sizes ranging from 0.41 to 1.26 points), high NART scores (effect sizes ranging from 0.44 to 1.19 points), higher number of years in formal education (effect sizes ranging from 0.22 to 0.78) and a higher mean of individuals belonging to the professional social class (effect sizes ranging from 0.12 to 0.70).

The effects personality seems to have on health behaviour and wellbeing in late life (Roberts, Kuncel, Shiner, et al., 2007) also emerged with moderate to strong correlations amongst the groups in this study (effect sizes ranging from 0.9 to 1.3 on personality trait scores). In line with literature on successful ageing (Roberts, Kuncel, Shiner, et al., 2007), individuals in the High Wellbeing group seemed to posses personality traits which seem to be important for psychological wellbeing in old age, namely, relatively low scores on the Neuroticism trait, and high scores on traits of Extraversion, Conscientiousness, Agreeableness, and Openness. Also interesting were the high scores on Neuroticism and high percentage of current smokers (effect sizes ranging from 0.22 to 0.39) in the Low Bio-Psychosocial group, since Neuroticism and smoking are typically known to be associated (Kornør & Nordvik, 2007; Terracciano & Coasta, 2004). Membership in the Low Bio-Psychosocial wellbeing group was also associated with lower scores on traits of Extraversion, Agreeableness and Conscientiousness. On the other hand, the Low Cognition group had the lowest scores on the Openness trait. This association has also been depicted in the literature, in which individuals scoring higher on intelligence tests, also tend to show higher scores on the Openness trait, and vice versa (Gregory, Nettelbeck & Wilson, 2010; Harris, 2004).

As depicted by the strength of the correlations, the most significant variables that seemed to be distinguishing the groups in this study were childhood IQ, Neuroticism scores and smoking behaviour. In light of these results, a number of implications related to the historical context of this cohort and its possible affects of wellbeing later on in life are discussed next.

6.6 Implications and future work

First, despite the limited educational opportunities at the time, individuals with high age-11 IQ, seemed to have been able to make use of their cognitive abilities to engage in health behaviours, make good lifestyle choices, and maintain high levels of wellbeing into old age as evidenced by their high scores on cognitive, physical and psychosocial measures in this study. Individuals from this sample were born in a time when education was limited - further education in the mid- 20th century was a choice between completing junior or secondary school, the latter of which would provide a school-leaving certificate (Paterson, Pattie & Deary, 2011). The mean years of total education in the High Wellbeing group in this study was only 11 years, which suggests that the majority of the sample got their school-leaving certificate. Although nowadays intelligence helps in furthering education, which is necessary for occupational advancement, educational credentials then were not as necessary as they are today, and raw intelligence was possibly a more direct pathway to advancement than it is now. This explains why education was not as important then. This does not mean that intelligence is less important now; however, the degree to which educational credentials indicate intelligence matters a lot more now than they did then. This also taps into social class changes in that a lot more opportunity was available then for a good environment for individuals holding a non-professional job than it is now. Intelligence and well-being associations are typically still observed once education and social class are controlled, suggesting the strong influence childhood IQ has on later life outcomes (Deary et al., 2007; Deary, Weiss & Batty, 2010; Strenze, 2007). In fact, higher childhood cognitive ability has been inversely associated with risk of developing depression, anxiety disorders, posttraumatic stress disorder, substance abuse and co-morbid mental disorders (Gale et al., 2001); and lower pre-morbid IQ scores are related to higher rates of all-cause mortality (Batty, Deary & Gottfredson, 2007). The associations between higher childhood IQ and higher scores on wellbeing domains may also possibly be explained by the notion that better physiological makeup is also reflected in cognitive ability. This is known as the System-Integrity Hypothesis (Deary, 2008; Whalley & Deary, 2001), which suggests that an efficient brain is a reflection of a “well-put-together” body (Deary, Weiss & Batty, 2010, p.63), the results of which are translated in intelligence test scores in particular and in overcoming environmental challenges in general, thus conferring resilience.

Neuroticism scores were also associated with wellbeing in old age, consistent with many other studies (Deary, Weiss & Batty, 2010; Lahey, 2009; Smith, 2006; Shipley, Weiss, Der, et al., 2007; Roberts, Kuneel, Shiner, Caspi & Goldberg, 2007; Abas, Hotopf & Prince, 2002; Wilson, Mendes de Leon, Bienias, Evans & Bennett, 2004; Paunonen, 2003). Neuroticism is an expression of emotional instability. Like other personality traits, it influences behaviour, thus contributing to decision-making and lifestyle patterns (Deary, Weiss & Batty, 2010). It also influences actions and reactions to daily situations and stressful experiences (Smith & Gallo, 2001), thus in a general sense, it is also linked with poor health habits (e.g. high alcohol intake) and as a consequence, poor health (e.g. alcohol-dependence). In one study Neuroticism explained between 19% and 88% of covariance with anxiety, depression, and alcohol and substance dependence disorders (Khan et al., 2005). It has also been found to be associated with health problems such as cardiovascular disease (Suls & Bunde, 2005), irritable bowel syndrome (Spiller, 2007), eating disorders (Malouff, Thorsteinsson, & Schutte, 2005), asthma (Huovinen, Kaprio & Koskenvuo, 2001), and hypochondriac tendencies (Costa & McCrae, 1987). Lastly, it also seems to impact on the way an individual copes with disease and treatment regiments, in that individuals with high neuroticism are more emotionally unstable thus less likely to adhere to these programs (Kenford et al., 2002; Scheier & Carver, 1993). This is important since individuals with higher traits of Neuroticism tend to have more persistent, disabling and co-morbid conditions such as cardiovascular disease, depression, and anxiety disorders (Smith & Mackenzie, 2006; Lahey, 2009; Kessler, Chiu, Demler &Walters, 2005). A positive association has been found to exist between economic costs and disorders associated with Neuroticism such as depression and anxiety disorders, the effects and costs of which exceeding those of other disorders not related to this trait (Cuijjpers, Smit, Pennix, de Graaf, ten Have & Beekman, 2010; Lahey, 2009). Although in youth Neuroticism is noted to have a protective effect against mortality since individuals high on this trait are more likely to avoid engaging in high-risk behaviour (Lee, Wadsworth & Hotopf, 2006), Neuroticism in old age is known for its association with a diminished lifespan (Roberts et al., 2007). From all of the five personality traits, in this study, scores on the Neuroticism trait distinguished amongst the groups most – individuals with low scores on this trait had accompanying good wellbeing, indicating that low scores on this trait are important for successful wellbeing in old age.

The third most notable variable that distinguished the High Wellbeing group from the rest was smoking behaviour. It is important to note here that this cohort comes from a generation in which smoking was fashionable, especially amongst the well off. It was only in the late 1950s, when individuals from this cohort were in their twenties that health risks of smoking emerged. Thus, results on smoking behaviour in this study reflected mainly whether individuals who had taken up smoking when they were young followed health advice and have quit now, or ignored it and are current smokers. In this study, the High Wellbeing group had a significantly lower percentage of smokers than the other two groups. Smoking is a learned behaviour, which nowadays more than before is associated with both intelligence and personality. Individuals with higher scores on Intelligence tests and Conscientiousness avoid or quit smoking, whereas individuals with high scores on Neuroticism are more likely to start and maintain the habit (Taylor, Hart, Smith et al., 2003). Research studying profiles of smokers have consistently documented high levels of Neuroticism (Terracciano & Costa, 2004; Vollrath & Torgersen, 2002; Ball, Tennen, Poling, Kranzler & Rounsaville, 1997; Conway, Kane, Ball, Poling & Rounsaville, 2003; Kornor & Nordvik, 2007). An explanation of the association between these two variables may be found in the self-medicating hypothesis, which suggests that individuals smoke and become dependent on narcotics because they are emotionally unstable, and use nicotine as a means to reduce stress and anxiety, although direction of causality, if present, is unknown (Kornor & Nordvik, 2007; Berlin et al., 2003). Individuals who quit smoking typically have lower scores on Neuroticism, suggesting that possibly, they have had lower scores before they started, which made it easier to quit (Terracciano & Costa, 2004; Parrotta, 1998). Smoking is also more prevalent in individuals who score lower on intelligence tests (Taylor et al., 2003; Richards, Jarvis, Thompson & Wadsworth, 2003; Kubicka, Matejeck, Dytrych & Roth, 2001). Smokers with higher IQ scores are also more likely to quit. This is seen in studies (Deary et al., 2003;Whalley et al, 2005), which show that once childhood IQ is controlled, current smokers have lower current IQ scores than both former and lifelong non-smokers. Again all of this has to be taken into context, especially since in the first half of the 20^{th} century smoking was a widely practised habit associated with wealth and social class (Gochmen, 1997). With the awareness of the health risks of smoking this behaviour has gradually shifted to a higher prevalence of smoking behaviour amongst individuals of lower intelligence and poorer backgrounds. Although smokers are not a homogenous group, a recurring profile seems to be reported across studies, mainly the similar personality patterns and cognitive status they share.

Results from this study also reflected this profile, in which individuals in the High Wellbeing group had a lower percentage of current smokers, lower scores on Neuroticism and higher childhood IQ scores.

Awareness of individual differences, especially relating to intelligence and personality, amongst health care professionals may have a clinical impact for risk prevention, improved compliance and better patient-practitioner relationships (Deary, Weiss & Batty, 2010). Results from this study showed that although wellbeing in late life seems to be a dimensional process, there are groups of individuals who seem to show uneven patterns of wellbeing, and that possibly such groups need more attention. Awareness of the effects of both intelligence and personality on behaviour may improve health interventions and treatment in groups of individuals who show inconsistent profiles of wellbeing e.g. individuals with low cognitive functioning but are still in good physical wellbeing and have a good network of support may benefit from interventions aimed at caregivers; whereas individuals with poorer networks but of higher cognitive ability may value better the patient-practitioner relationship which in turn impacts on compliance. Emerging fields of cognitive and personological epidemiology aim to diminish health and wellbeing inequalities by providing care and support as needed (Deary, Weiss & Batty, 2010). Results such as these help in distinguishing amongst possible groups of individuals displaying uneven profiles of wellbeing. Longitudinal work on this data is important for future research on successful ageing, and for prevention programs targeting at risk older adults.

6.7 Final conclusions

The primary aim of this study was to identify potential profiles of overall wellbeing amongst 70-year-old individuals in the LBC1936. Results from this study suggested that intelligence and personality are important influences of health behaviours and subsequent wellbeing in old age. A high childhood IQ, low Neuroticism and not smoking were better associated with health in old age than total number of years in education or social class. This study showed that intelligence and personality traits seem to affect lifestyle choices, daily patterns of health behaviour, and ultimately overall wellbeing. These traits seemed to also affect health practices, such as not smoking, which was also associated with high wellbeing in old age. These variables, which represent three different areas of cognition, personality and health behaviour, also suggested the presence of a strong dimension present in this cohort's wellbeing domains: The majority scored relatively well across domains of wellbeing and associated co-variables, which implied a uni-dimensional result of wellbeing in this age group, with indistinct smaller groups doing less well in some areas and relatively better in others.

Table 6.1

Correlation coefficients of the components of the three domains of wellbeing.

	All domains	1.	2.	3.	4.	5.	6.	7.	8.	9.
1.	*g*	-								
2.	Memory	.46**	-							
3.	Speed	.27**	.20**	-						
4.	Physical Function	.10**	.00	.06	-					
5.	QOL	.23**	.10**	.12**	.30**	-				
6.	Emotional Wellbeing	.20**	.10**	.06	.20**	.57**	-			
7.	Physical Fitness	.31**	.12**	.16**	.30**	.33*	.19*	-		
8.	Lack of Inflammation	.00	.05	.00	-.02	-.07*	-.05	-.02	-	
9.	Lack of Morbidity	.22**	.05	.09**	.28**	.32**	.23**	.29**	.00	-

Note. g = General Cognitive Ability. QOL = Quality of Life.

Table 6.2

Model information criteria for each of the two-, three-, four-, five-, six- and seven-group solutions.

Group-solution	AIC	BIC	Adjusted BIC
Two	23361.4	23501.3	23412.4
Three	23144.9	23334.7	23214.0
Four	23018.3	23258.1	23105.6
Five	22910.4	23200.1	23015.8
Six	22835.0	23174.7	22958.7
Seven	22769.6	23159.2	22911.5

Note. AIC = Akaike information criterion. BIC = Bayesian information criterion. Adjusted BIC = (n* = (n* = (n + 2) / 24).

Table 6.3

Total number and percentages of individuals per group, and probabilities of falling into two latent groups according to the nine components of wellbeing in the Lothian Birth Cohort 1936.

Group	N	%	Probability of group membership 1	Probability of group membership 2
1	213	19.5	0.90	0.10
2	878	80.5	0.04	0.96

Table 6.4

Total number and percentages of individuals per group and, probabilities of falling into three latent groups according to the nine components of wellbeing in the Lothian Birth Cohort 1936.

Group	N	%	Probability of group membership 1	Probability of group membership 2	Probability of group membership 3
1	221	20.3	.81	.05	.14
2	158	14.5	.07	.87	.06
3	712	65.3	.07	.01	.91

Table 6.5

Total number and percentages of individuals per group, and probabilities of falling into four latent groups according to the nine components of wellbeing in the Lothian Birth Cohort 1936.

Group	N	%	Probability of group membership 1	Probability of group membership 2	Probability of group membership 3	Probability of group membership 4
1	272	24.9	0.78	0.05	0.16	0.00
2	153	14	0.09	0.86	0.05	0.00
3	651	56.7	0.09	0.01	0.90	0.00
4	15	1.4	0.07	0.02	0.00	0.91

Table 6.6

Total number and percentages of individuals per group, and probabilities of falling into five latent groups according to the nine components of wellbeing in the Lothian Birth Cohort 1936.

Group	N	%	Probability of group membership 1	Probability of group membership 2	Probability of group membership 3	Probability of group membership 4	Probability of group membership 5
1	79	7.2	0.84	0.09	0.04	0.03	0.00
2	175	16.0	0.03	0.73	0.08	0.03	0.14
3	205	18.8	0.02	0.06	0.80	0.01	0.11
4	51	4.7	0.03	0.06	0.04	0.81	0.07
5	581	53.3	0.00	0.05	0.06	0.01	0.88

Table 6.7

Total number and percentages of individuals per group, and probabilities of falling into six latent groups according to the nine components of wellbeing in the Lothian Birth Cohort 1936.

Group	N	%	Probability of group membership 1	Probability of group membership 2	Probability of group membership 3	Probability of group membership 4	Probability of group membership 5	Probability of group membership 6
1	247	22.6	0.78	0.02	0.01	0.00	0.07	0.12
2	78	7.1	0.04	0.86	0.03	0.00	0.08	0.00
3	48	4.4	0.07	0.03	0.80	0.00	0.05	0.06
4	14	1.3	0.06	0.02	0.00	0.92	0.00	0.00
5	155	14.2	0.08	0.03	0.03	0.00	0.73	0.14
6	549	50.1	0.07	0.00	0.00	0.00	0.04	0.87

Table 6.8

Total number and percentages of individuals per group, and probabilities of falling into seven latent groups according to the n components of wellbeing in the Lothian Birth Cohort 1936.

Group	N	%	Probability of group membership 1	Probability of group membership 2	Probability of group membership 3	Probability of group membership 4	Probability of group membership 5	Probability of group membership 6	Prob grou mem 7
1	235	21.5	0.74	0.01	0.00	0.04	0.06	0.15	0.00
2	45	4.1	0.04	0.83	0.02	0.02	0.05	0.05	0.00
3	54	4.9	0.00	0.03	0.85	0.05	0.07	0.00	0.00
4	78	7.1	0.10	0.02	0.05	0.76	0.06	0.00	0.01
5	172	15.8	0.08	0.03	0.01	0.03	0.73	0.12	0.00
6	496	45.5	0.09	0.01	0.00	0.00	0.05	0.85	0.00
7	11	1.0	0.02	0.00	0.00	0.00	0.00	0.00	0.98

Table 6.9

Model information criteria for each of the two, three, four, and five group solutions for Sub-sample 1.

Group solution	AIC	BIC	Adjusted BIC
Two	11772.3	11892.9	11804.1
Three	11689.1	11852.8	11732.2
Four	11647.7	11854.5	11702.1
Five	11574.7	11824.6	11640.5

Table 6.10

Model information criteria for each of the two, three, four, and five group solutions for Sub-sample 2.

Group solution	AIC	BIC	Adjusted BIC
Two	11605.1	11725.4	11636.5
Three	11485.6	11648.8	11528.2
Four	11416.4	11622.6	11470.2
Five	11362.8	11611.9	11427.8

Table 6.11

Percentages of participants for each of the two, three, four, and five group solutions for Sub-samples 1 and 2.

	%				
Group	1	2	3	4	5
Sub-sample 1					
Two	22.8	77.2			
Three	20.9	19.3	59.7		
Four	19.8	5.1	68.9	7.1	
Five	24.6	4.2	17.1	6.2	43.1
Sub-sample 2					
Two	81.5	18.5			
Three	75.1	14	10.9		
Four	21.2	9.4	68.3	1.1	
Five	24.2	5.7	56.8	1.3	12.1

Table 6.12

Total number of cases (percentages in parentheses) of belonging to their own group at a probability of 0.90.

Group	Total number of cases	Number of cases with < 0.90 probability (%)
1	221 (20.3)	90 (40.7)
2	158 (14.5)	96 (60.8)
3	712 (65.3)	522 (73.3)

Table 6.13

Means of the variables and significance values for the three domains of Cognitive Ability, Psychosocial Wellbeing, and Physical Fitness for each of the 3 groups (SDs in parentheses) of the Lothian Birth Cohort 1936.

Class	N (%)	*g*	Memory	Speed	Physical Function	QOL	Emotional Wellbeing	Physical Fitness	Lack of Inflammation	Lack of Morbidity
Low Cognition	221 (20.3)	-.74 (.5)	-.95 (.6)	-.29 (.7)	.18 (1.0)	-.04 (.8)	-.03 (.9)	-.22 (.9)	-.02 (1.0)	.00 (.9)
Low Bio-psychosocial	158 (14.5)	-.42 (.7)	-.02 (.8)	-.08 (.6)	-1.08 (.9)	-1.54 (.9)	-1.33 (1.0)	-1.05 (1.0)	.14 (1.0)	-1.06 (1.0)
High Wellbeing	712 (65.3)	.33 (.6)	.31 (.6)	.13 (.4)	.16 (.9)	.32 (.8)	.30 (.8)	.29 (.8)	-.03 (1.0)	.23 (.9)
df		2	2	2	2	2	2	2	2	2
F		354.7	309.8	53.1	103.7	304.1	252.0	160.0	1.74	134.3
p		.001	.001	.001	.001	.001	.001	.001	.176	.001

Note. Significant differences were present between all groups, except for the High Wellbeing and the Low Bio-Psychosocial groups on physical function.

Table 6.14

Component loadings for the principal components using varimax and oblimin rotations of the three variables reflecting the nine components in the three domains.

Variables	Varimax rotation component loadings		Oblimin rotation components loadings	
	1	2	1	2
QOL	.77	.03	.77	.05
Emotional Wellbeing	.67	.01	.67	.03
Physical Function	.62	-.12	.62	-.11
Low Morbidity	.60	.12	.60	.14
Physical Fitness	.58	.20	.59	.22
Memory	-.00	.80	.03	.80
g	.30	.75	.33	.76
Speed	.12	.49	.14	.49
Low Inflammation	-.10	.18	-.09	.18

Note. QOL = quality of life. *g* = General cognitive ability.

Table 6.15

Means and significance values for each of the two domains of Bio-Psychosocial Wellbeing and Cognitive Function for each of the 3 groups (SDs in parentheses) of the Lothian Birth Cohort 1936.

Class	N (%)	Bio-Psychosocial Wellbeing	Cognitive Function
Low Cognition	221 (20.3)	-.02 (.7)	-1.34 (.7)
Low Bio-psychosocial	158 (14.5)	-2.00 (.7)	-.07 (.9)
High Wellbeing	712 (65.3)	.33 (.6)	.37 (.7)
df		2	2
F		446.0	313.4
p		.001	.001

Table 6.16

Raw means, standard deviations (SDs) and significance values for group comparisons of age-11 IQ, NART, number of years in formal education and social class for each of the 3 groups in the Lothian Birth Cohort 1936.

Variables	Low Cognition		Low Bio-psychosocial		High Wellbeing				
	Mean	SD	Mean	SD	Mean	SD	df	F	*p*
Age 11 IQ	88.1	13.8	94.7	17.2	104.6	12.3	2	129.9	.001
NART	28.3	8.0	31.9	8.2	37.1	6.8	2	58.7	.001
Yrs. In Educ.	10.2	0.8	10.4	1.0	11.0	1.2	2	58.7	.001

Note. NART = National Adult Reading Test. No adjustment of significance levels for multiple testing.

Table 6.17

Proportions, percentages and significance values for sex, marital status, living status, and social class status for each of the 3 groups in the Lothian Birth Cohort 1936.

Variables	Low Cognition		Low Bio-psychosocial		High Wellbeing				
	n	%	N	%	n	%	df	X^2	*p*
Sex									
Male	128	57.9	74	46.8	346	48.6			
Female	93	42.1	84	53.2	366	51.4			
N	221	100	158	100	712	100	2	6.7	.035
Marital status									
Married	149	67.4	99	62.7	530	74.5			
Single	13	5.9	12	7.6	40	5.6			
Divorced	25	11.3	18	11.4	41	5.8			
Cohabiting	4	1.8	2	1.3	11	1.5			
Widowed	29	13.1	27	17.1	90	12.6			
Other	1	0.5	0	0	0	0			
N	221	100	158	100	712	100	10	20.0	.034
Living status									
Alone	60	27.1	49	31.0	157	22.1			
Not alone	161	72.9	109	67.0	555	77.9			
N	221	100	158	100	712	100	2	6.8	.029
Social Class									
I	13	6	15	9.9	162	23			
II	65	30.2	55	36.4	282	40.1			
III (skilled)	55	25.6	28	18.5	163	23.2			
III (unskilled)	68	31.6	43	28.5	77	10.9			
IV	12	5.58	7	4.6	19	2.7			
V	2	0.9	3	2	1	0.1			
	215	100	151	100	704	100	10	103.7	.001

Table 6.18

Tukey's HSD post-hoc results for age 11 IQ, NART, years in education and social class.

Effect	Compare	Effect size Cohen's *d*	Mean difference	95% Confidence Interval	
				Lower	Higher
Age 11 IQ	1-2	0.42	-6.6***	-10.0	-3.2
	1-3	1.26	-16.5***	-19.1	-14.0
	2-3	0.41	-10.0***	-12.8	-7.2
NART	1-2	0.44	-3.9***	-5.7	-2.1
	1-3	1.19	-9.0***	-10.3	-7.7
	2-3	0.69	-5.1***	-6.7	-3.6
Years in Education	1-2	0.22	-0.4	-0.5	0.3
	1-3	0.78	-0.8***	-1.0	-0.6
	2-3	0.54	-0.6***	-0.8	-0.4

Note. * $p < .05$ ** $p < .01$ *** $p < .001$. 1 = Low Cognition. 2 = Low Bio-psychosocial. 3 = High Wellbeing.

Table 6.19

Odd ratios (OR) for group membership for the demographic measures in raw scores in the Lothian Birth Cohort 1936 sample, with 95% confidence intervals (CI).

Variable	OR Low Cognition (vs.High Wellbeing)	95% CI		OR Low Bio-psychosocial (vs. High Wellbeing)	95% CI	
		Lower	Upper		Lower	Upper
Sex, male	1.47	.99	2.19	1.11	.75	1.65
Age 11 IQ	0.95***	.94	.97	0.97**	.95	.99
NART	0.92***	.89	.95	0.95*	.92	.99
Yrs in Educ.	0.70**	.55	.90	0.86	.68	1.07
Marital status, not married	1.26	.48	3.28	0.68	.28	1.67
Living Status, alone	0.80	.32	1.95	0.97	.41	2.26
Social Class, manual	1.11	.88	1.42	1.15	.90	1.47

Note. The High Cognition group is baseline. OR = odds ratio. CI = Confidence interval. *p*-values have been adjusted for multiple testing using Bonferroni correction. * p < .05 ** p < .01 *** p < .001. OR = Odds Ratio. CI = Confidence Interval.

Table 6.20

Raw means, standard deviations (SDs), and significance values of comparisons of Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness in the 3 groups in the Lothian Birth Cohort 1936.

Variables	Low Cognition		Low Bio-psychosocial		High Wellbeing				
	Mean	SD	Mean	SD	Mean	SD	df	F	*p*
Neuroticism	18.0	7.0	24.5	7.7	15.4	6.8	2	93.1	.001
Extraversion	27.0	5.6	23.1	5.8	27.7	5.7	2	34.3	.001
Openness	23.9	4.7	25.0	5.9	26.8	5.9	2	20.5	.001
Agreeableness	32.6	5.2	31.6	5.4	34.0	5.1	2	14.4	.001
Conscientiousness	34.5	5.5	31.0	6.7	35.4	5.7	2	31.5	.001

Note. No adjustment of significance levels for multiple testing.

Table 6.21

Tukey's HSD post-hoc results for Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness.

Effect	Compare	Effect size	Mean difference	95% Confidence Interval	
		Cohen's *d*		Lower	Higher
Neuroticism	1-2	0.9	-6.5***	-8.4	-4.6
	1-3	0.4	2.6	1.2	4.0
	2-3	1.3	9.1***	7.5	10.7
Extraversion	1-2	0.7	4.0***	2.4	5.6
	1-3	0.2	-.67	-1.8	0.5
	2-3	0.8	-4.6***	-6.0	-3.3
Openness	1-2	0.2	-1.1	-2.6	.5
	1-3	0.5	-2.8***	-4.0	-1.8
	2-3	0.3	-1.8**	-3.1	-0.5
Agreeableness	1-2	0.2	.99	-.4	2.4
	1-3	0.3	-1.4**	-2.5	-.4
	2-3	0.5	-2.4***	-3.6	-1.2
Conscientiousness	1-2	0.6	3.5***	2.0	5.2
	1-3	0.2	-.9	-2.1	0.3
	2-3	0.7	-4.5***	-5.8	-3.1s

Note. * $p < .05$ ** $p < .01$ *** $p < .001$. 1 = Low Cognition. 2 = Low Bio-psychosocial. 3 = High Wellbeing.

Table 6.22

Odd ratios (OR) for group membership for the personality measures of Lothian Birth Cohort 1936 participants, with 95% confidence interval (CI).

Variable	OR Low Cognition (vs. High Wellbeing)	95% CI		OR Low Bio-psychosocial (vs. High Wellbeing)	95% CI	
		Lower	Upper		Lower	Upper
Neuroticism	1.06***	1.03	1.09	1.16***	1.12	1.20
Extraversion	1.03	.99	1.06	0.95*	.91	.99
Openness	0.91***	.88	.95	0.95*	.91	.99
Agreeableness	0.97	.94	1.01	0.97	.93	1.02
Conscientiousness	1.00	.96	1.03	0.94**	.91	.98

Note. The High Cognition group is baseline. OR = odds ratio. CI = Confidence interval. *p*-values have been adjusted for multiple testing using Bonferroni correction. * p < .05 ** p < .01 *** p < .001.

Table 6.23

Raw means, standard deviations (SDs) and significance values of BMI and total units of alcohol per week for each of the 3 groups in the Lothian Birth Cohort 1936.

Variables	Low Cognition		Low Bio-psychosocial		High Wellbeing				
	Mean	SD	Mean	SD	Mean	SD	df	F	*p*
Units of alcohol/week	10.2	14.8	9.0	16.0	11.0	13.6	2	1.2	.298
BMI	28.1	4.4	29.1	5.1	27.4	4.1	2	10.1	.001

Note. BMI = Body Mass Index. . No adjustment of significance levels for multiple testing.

Table 6.24

Proportions, percentages and significance values for comparisons of APOE e4 allele and smoking status in the 3 groups in the Lothian Birth Cohort 1936.

Variables	Low Cognition		Low Bio-psychosocial		High Wellbeing		df	X^2	*p*
*APOE*e4									
Not Present	152	72.4%	109	73.6%	461	68.8%			
Present	58	27.6%	39	26.4%	209	31.2%			
N	210	100%	148	100%	670	100%	2	1.9	.379
Smoking Category									
Never smoked	93	42.1%	50	31.6%	331	46.5%			
Ex-smoker	90	40.7%	72	45.6%	309	43.4%			
Current Smoker	38	17.2%	36	22.8%	72	10.1%			
N	221	100%	158	100%	712	100%	4	25.7	.001

*Note. APOE*e4 = Apolipoprotein allele e4.

Table 6.25

Tukey's HSD post-hoc results for BMI and Smoking category (current smokers).

Effect	Compare	Effect size Cohen's *d*	Mean difference	95% Confidence Interval Lower	 Higher
BMI	1-2	0.21	-1.0	-2.1	0
	1-3	0.16	0.7	-0.1	1.4
	2-3	0.37	1.7***	.8	2.5
Smoking category	1-2	0.22	-0.2	-0.3	.01
	1-3	0.16	.12	-0.1	0.4
	2-3	0.39	.28***	.13	.42

Note. * p < .05 ** p < .01 *** p < .001. BMI = Body mass index. 1 = Low Cognition. 2 = Low Bio-psychosocial. 3 = High Wellbeing.

Table 6.26

Odd ratios (OR) for group membership for health measures of Lothian Birth Cohort 1936 participants, with 95% confidence interval (CI)

Variable	OR Low Cognition (vs. High Wellbeing)	95% CI		OR Low Bio-psychosocial (vs. High Wellbeing)	95% CI	
		Lower	Upper		Lower	Upper
Units alcohol/wk.	1.00	.99	1.01	0.99	.97	1.00
BMI	1.05*	1.01	1.09	1.10***	1.05	1.14
Smoking, never smoked against current and ex-smokers combined	0.52**	.32	.83	0.24***	.14	.41
APOE e4	1.16	.82	1.64	1.19	.79	1.80

Note. The High Cognition group is baseline. OR = odds ratio. CI = Confidence interval. P-values have been adjusted for multiple testing using Bonferroni correction. * $p < .05$ ** $p < .01$ *** $p < .00$

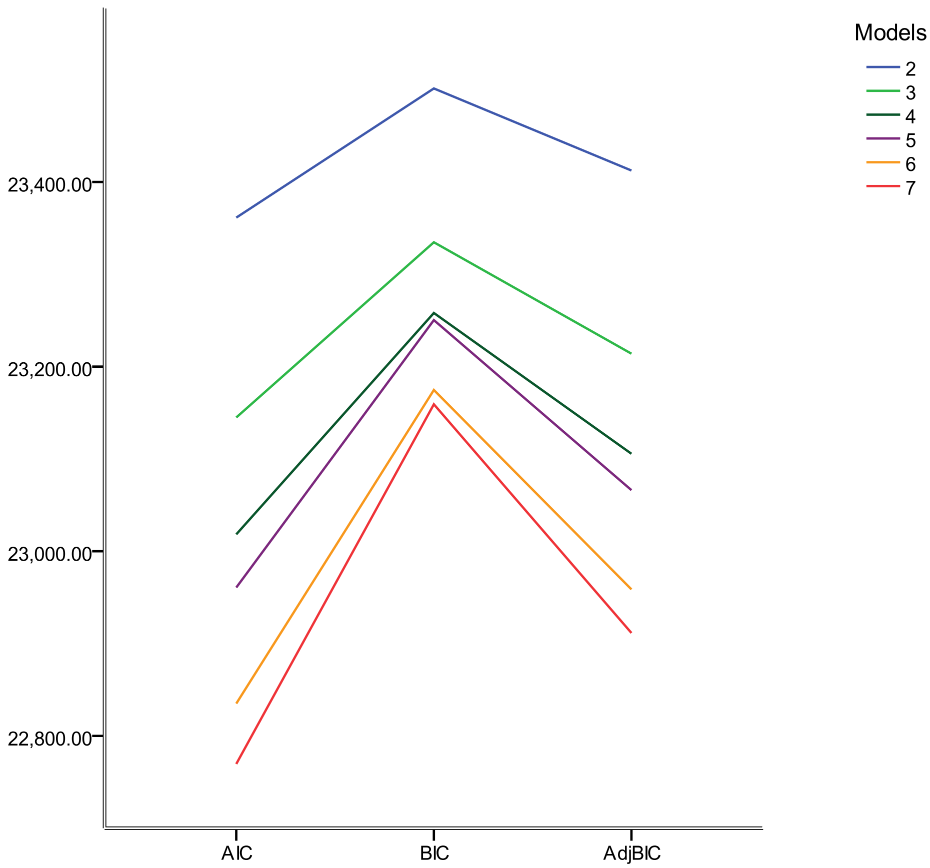


Figure 6.1 Model-fit criteria according to the Akaike information criterion (AIC), the Bayesian information criterion (BIC), and the adjusted BIC = (n* = (n* = (n + 2) / 24) for each of the two-, three-, four-, five-, six- and seven- group solutions.

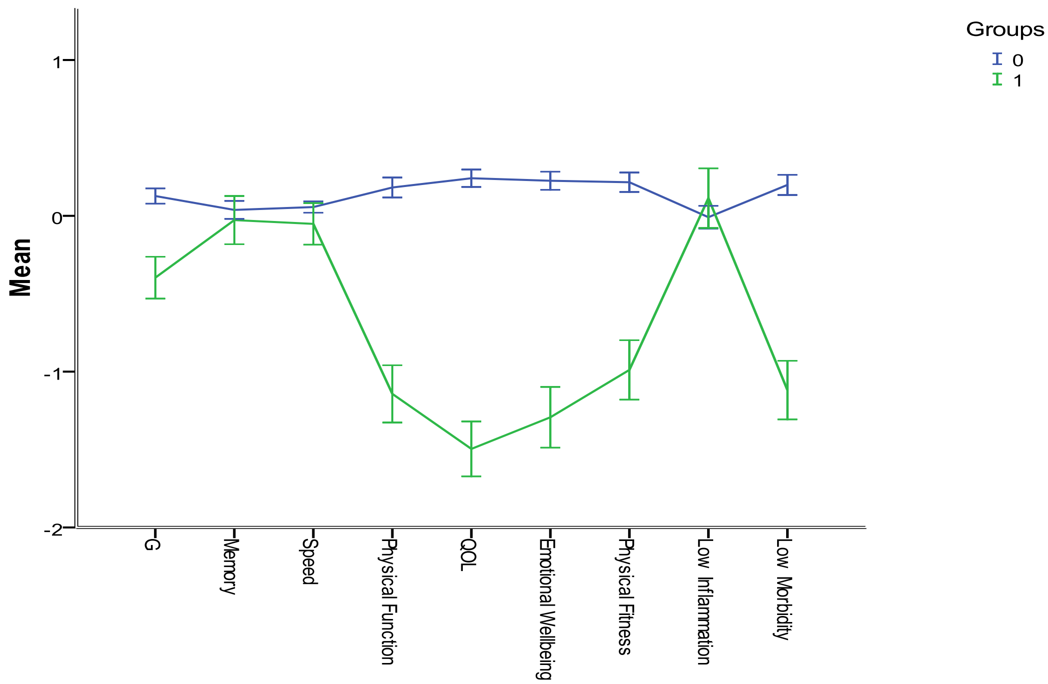


Figure 6.2. Mean scores on the nine variables as depicted by two groups as generated from latent class analysis with 95% confidence intervals. *Note*. *g* = General Cognitive Ability. QOL = Quality of Life.

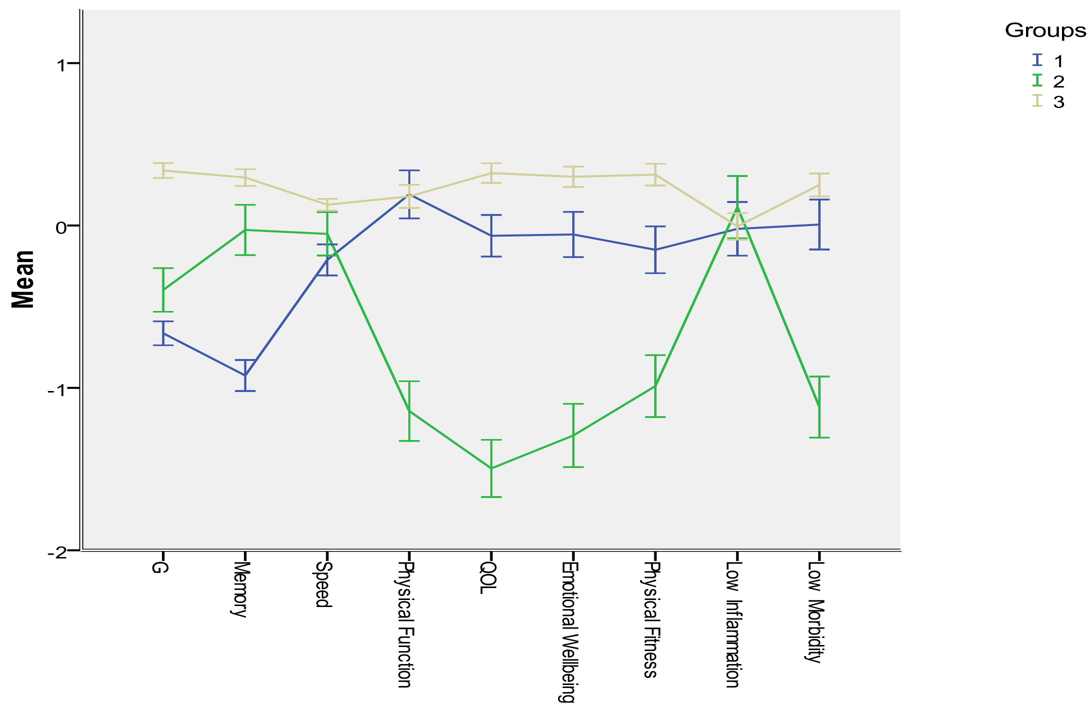


Figure 6.3. Mean scores on the nine variables as depicted by three groups as generated from latent class analysis with 95% confidence intervals. *Note*. *g* = General Cognitive Ability. QOL = Quality of Life.

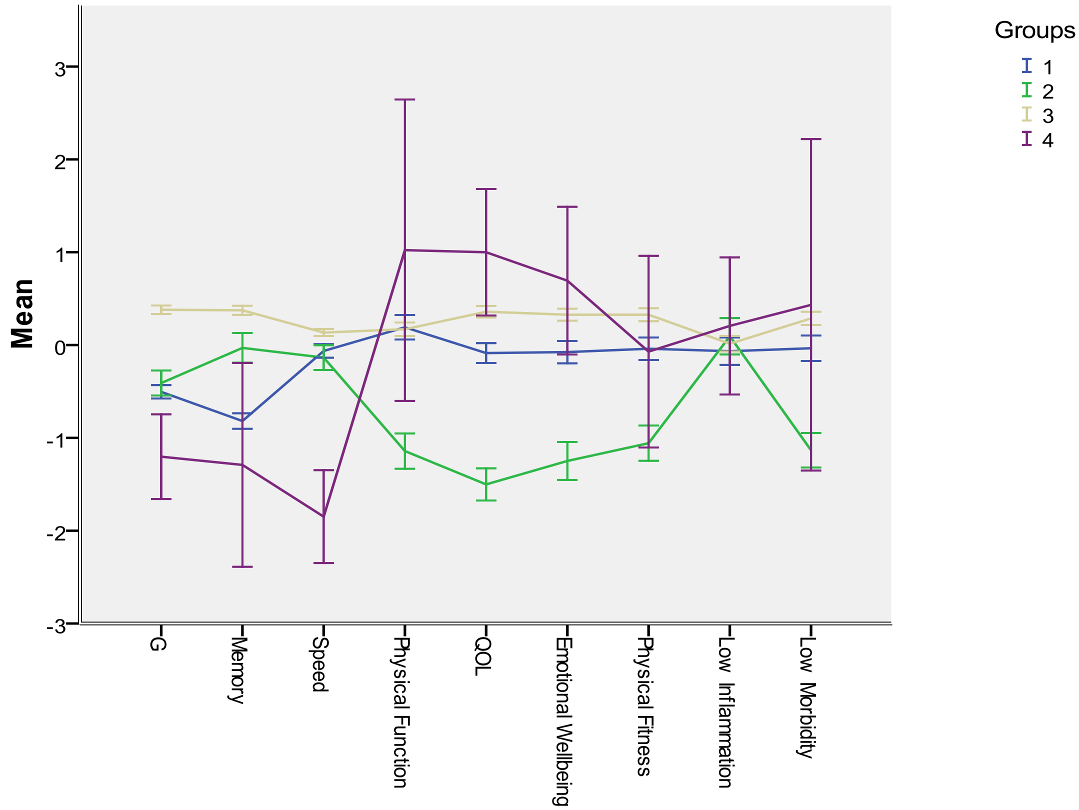


Figure 6.4. Mean scores on the nine variables as depicted by four groups as generated from latent class analysis with 95% confidence intervals. *Note*. *g* = General Cognitive Ability. QOL = Quality of Life.

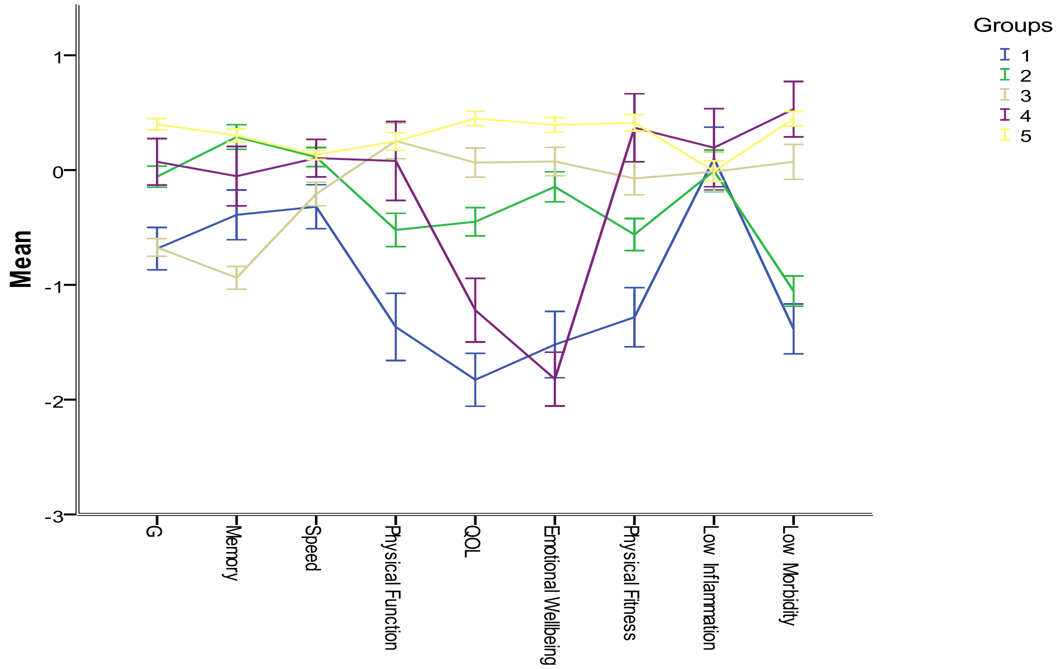


Figure 6.5. Mean scores on the nine variables as depicted by five groups as generated from latent class analysis with 95% confidence intervals. *Note*. *g* = General Cognitive Ability. QOL = Quality of Life.

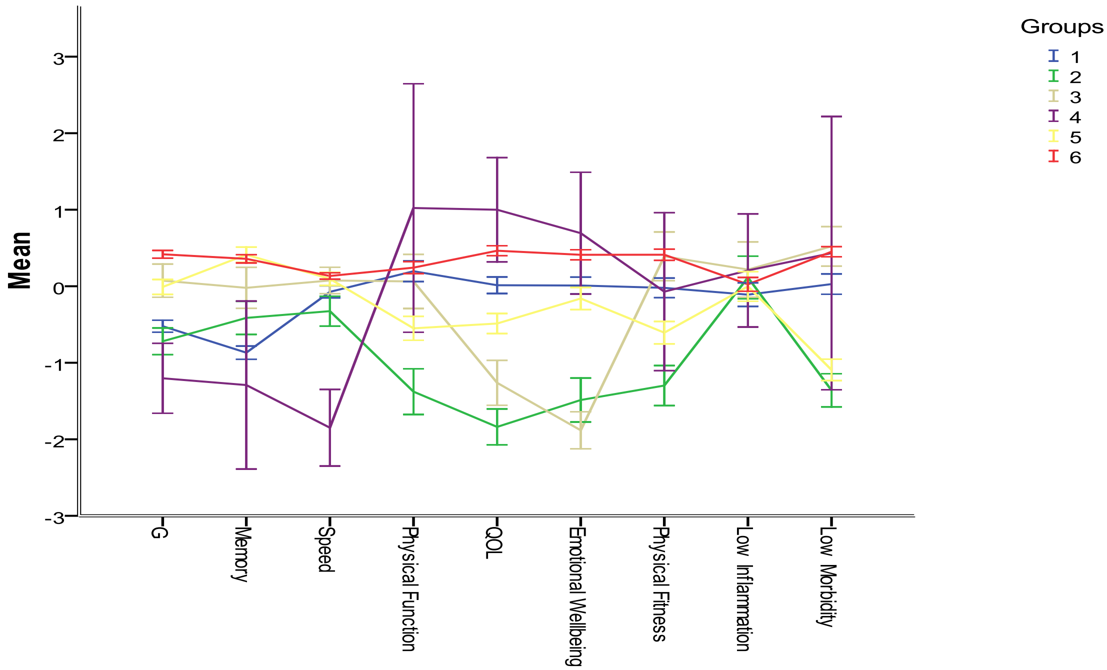


Figure 6.6. Mean scores on the nine variables as depicted by six groups as generated from latent class analysis with 95% confidence intervals. *Note*. *g* = General Cognitive Ability. QOL = Quality of Life.

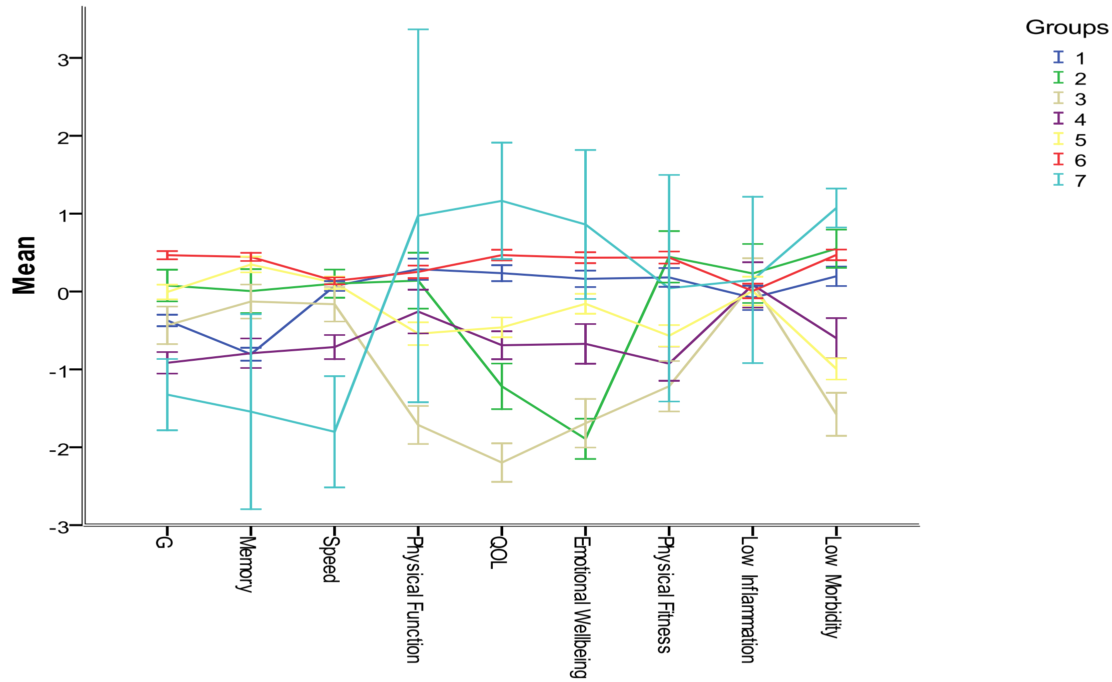


Figure 6.7. Mean scores on the nine variables as depicted by seven groups as generated from latent class analysis with 95% confidence intervals. *Note*. *g* = General Cognitive Ability. QOL = Quality of Life.

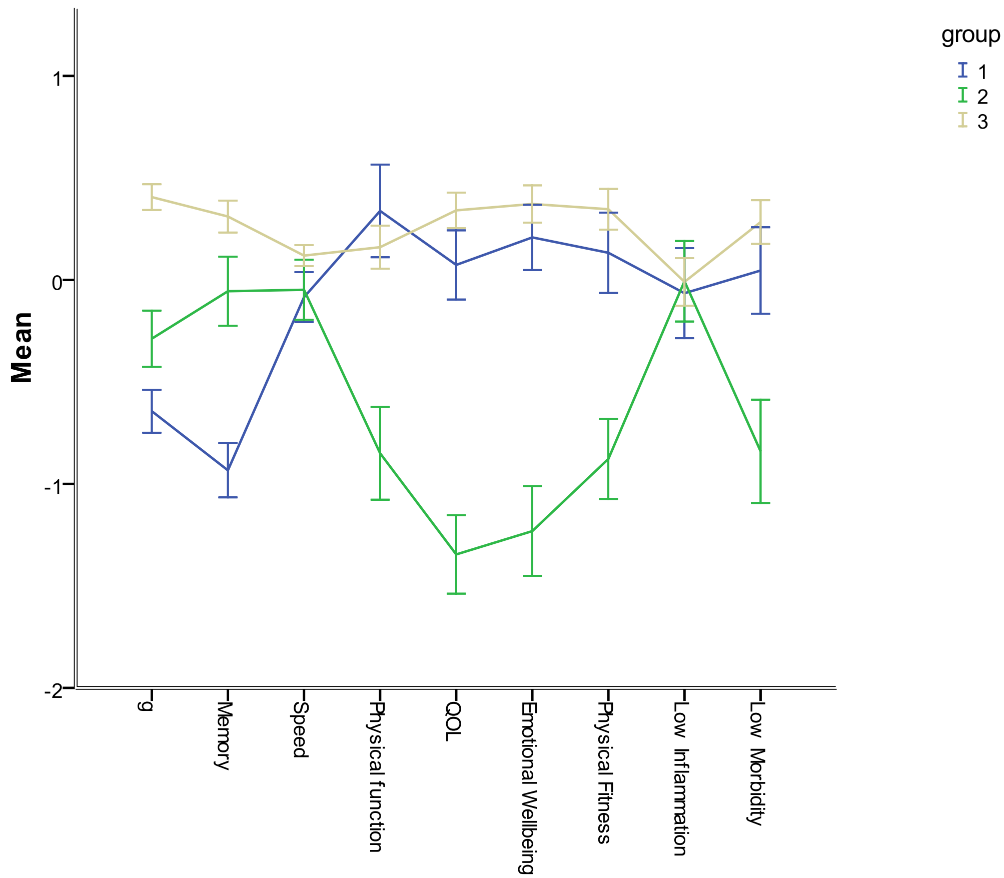


Figure 6.8. Mean scores on the nine variables as depicted by three groups in Sub-sample 1 as generated from latent class analysis with 95% confidence intervals. *Note*. *g* = General Cognitive Ability. QOL = Quality of Life.

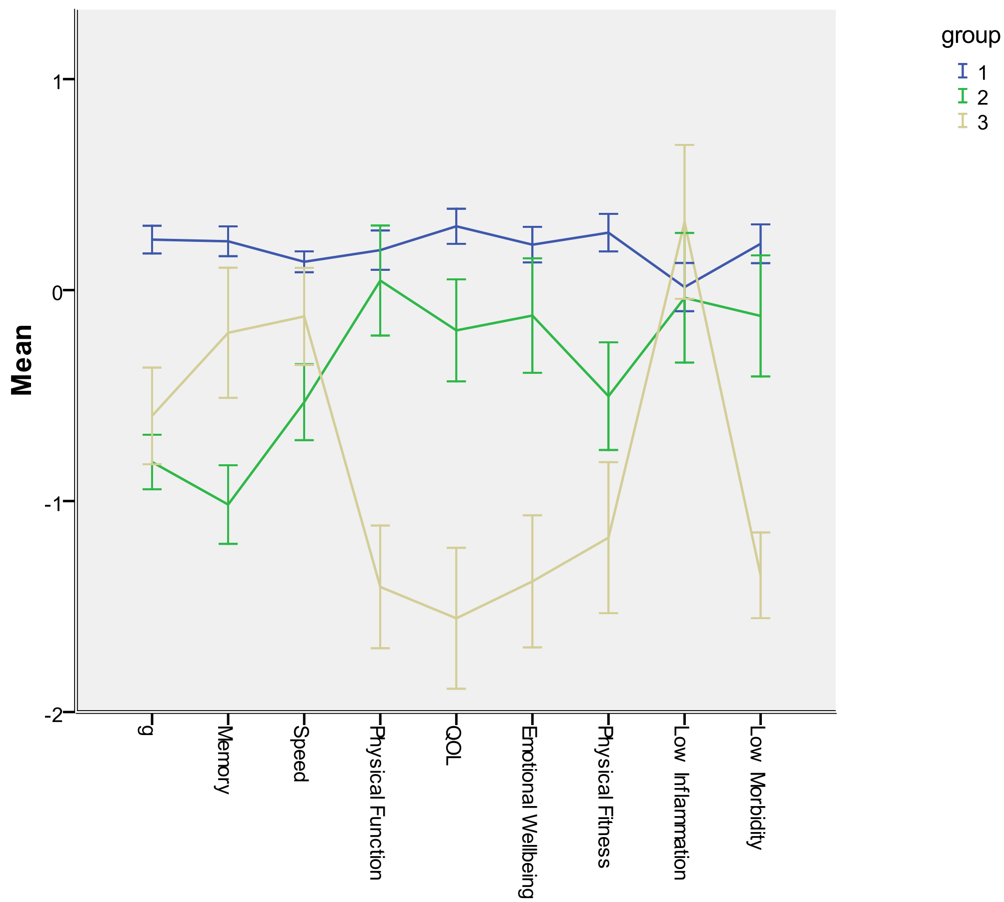


Figure 6.9. Mean scores on the nine variables as depicted by three groups in Sub-sample 2 as generated from latent class analysis with 95% confidence intervals. *Note*. *g* = General Cognitive Ability. QOL = Quality of Life.

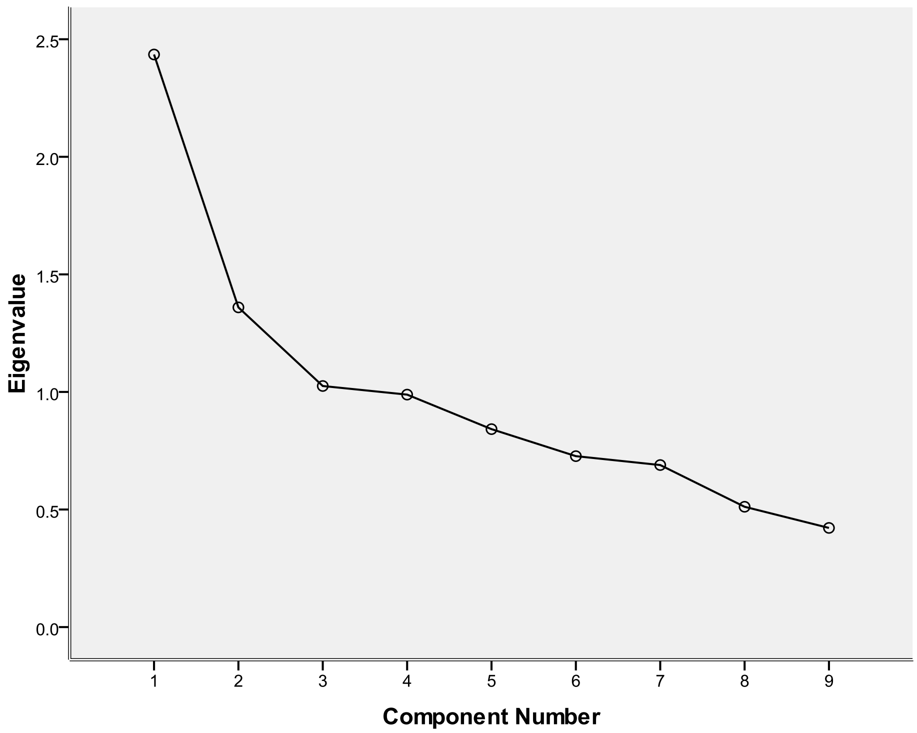


Figure 6.10. The scree plot for the nine variables displaying inflexions that would justify retaining one component.

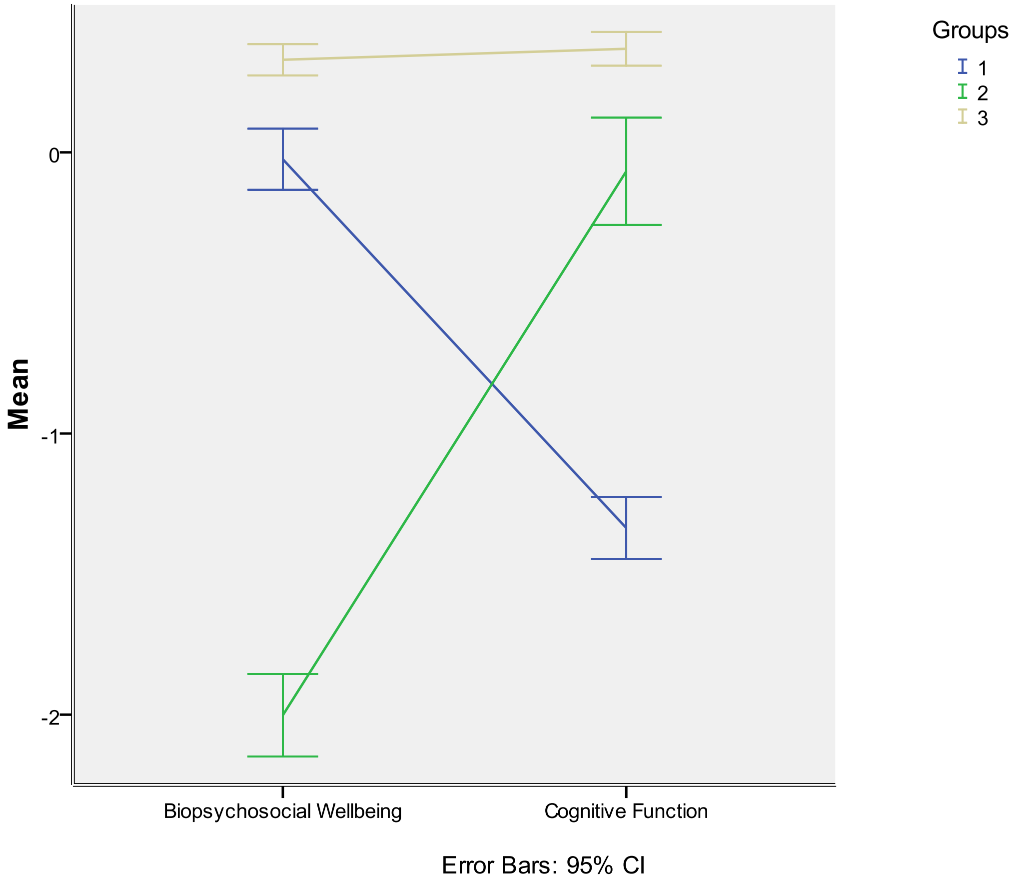


Figure 6.11. The groups' mean scores on the two components of wellbeing, namely Biopsychosocial Wellbeing, and Cognitive Function as derived from a PCA on the Cognitive Domain, the Psychosocial Domain, and the Physical Domain, with 95% confidence intervals, as generated from LCA for the Lothian Birth Cohort 1936 sample. *Note.* 1 = Low Cognition. 2 = Low Bio-Psychosocial. 3 = High Wellbeing.

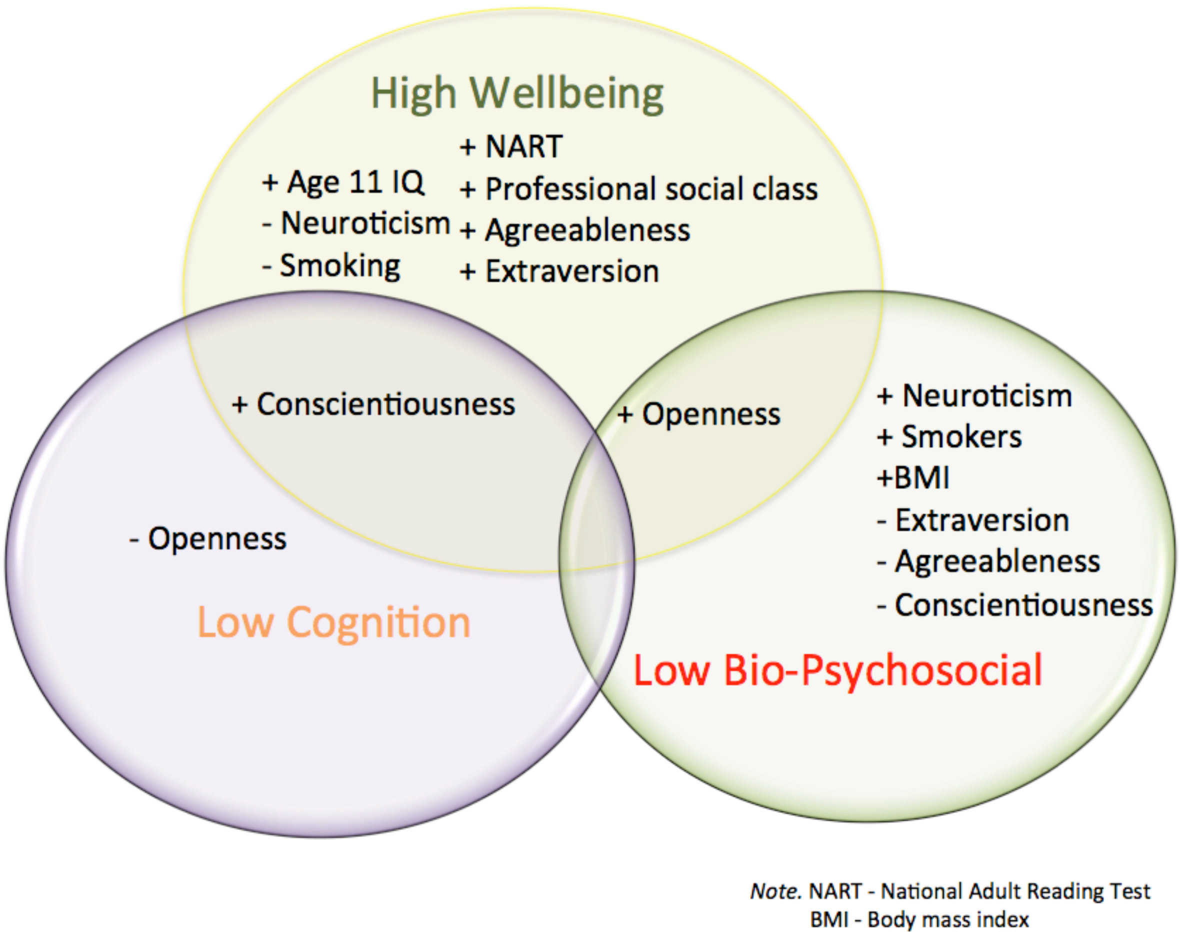


Figure 6.12. Venn diagram illustrating the similarities and differences characterising the groups.

Chapter 7: In how many ways can one age successfully? Discussion

This thesis adopted a multidimensional approach to successful ageing by studying domains of cognitive ability, psychosocial and emotional wellbeing, and physical fitness in the Lothian Birth Cohort 1936 (LBC1936) at 70 years of age. The three main aims were to explore the structure of the domains of wellbeing, to find out whether distinct groups of individuals that displayed different patterns across domains of wellbeing were present, and if so, to identify their characteristics and the variables associated with them. In each of the three domains I explored all three aims individually. First, the domains were studied separately – Cognitive Ability (Chapter 3), Psychosocial Wellbeing (Chapter 4), and Physical Fitness (Chapter 5). Then they were studied together (Chapter 6). In the first three empirical chapters, I explored profiles of wellbeing within domains and, in the last one, across domains to find out how patterns of wellbeing unfolded when studying different domains of wellbeing separately and how this might change when studying them together, and if so, in what ways. Ultimately, I wanted to find out what constitutes success in old age, what is associated with it, and if there are different ways of reaching it.

7.1 Summary of results

The first study in this thesis explored Cognitive Ability (Chapter 3). Scores on three components – General Cognitive Ability (*g*), Memory, and Speed – reflecting this domain, were entered into latent class analysis (LCA). A 3-group solution reflecting patterns of cognitive ability in this cohort was selected for further analysis. Results indicated the presence of a strong dimension with a large high-ability group and two smaller average- and low- ability groups. Results failed to show any indication of uneven patterns of scores in this domain. This is probably due to the high associations present amongst the cognitive components, whereby low ability in one is typically reflective of low ability in another (Salthouse, 2004; Tucker-Drob, 2010). Individuals in the High Cognitive Ability group also had positive patterns of scores in other areas of wellbeing - higher childhood intelligence, more years in education, better health, and higher mean scores on Agreeableness and Openness personality traits. The main findings of this study confirmed previous research that cognitive abilities are highly associated; ability in one cognitive component is typically reflective of abilities in other cognitive components; and these abilities are associated with other important areas of life, such as education, health and lifestyle, even up to old age (e.g. Deary et al., 2000; Fiocco & Yaffe, 2010; Gow et al., 2007; Starr et al., 2000).

Psychosocial Wellbeing was the second domain of function explored in the LBC1936 in this thesis (Chapter 4). Individuals were grouped according to their scores on components of Quality of Life, Emotional Wellbeing, and Physical Function. A 5-group solution was selected to reflect the cohort's wellbeing profiles on this domain. Results here indicated a spectrum of wellbeing. Three groups of individuals scored either consistently highly or low across components. Two of the groups demonstrated uneven patterns of wellbeing: one group scored relatively highly on physical function, but low on emotional wellbeing (High Function/Low Spirits), whereas another group showed low physical function but high emotional wellbeing (Low Function/High Spirits). This supported previous literature that also found uneven profiles of wellbeing across groups (e.g. Hsu & Jones, 2012; Ko et al., 2007; Prucho et al., 2010; Smith & Baltes, 1997). Results also indicated personality traits, especially Neuroticism and Conscientiousness, as strong discriminators among the groups: the Low Function/High Spirits group showed low scores on the Conscientiousness trait (reflected in its behaviour of high smoking behaviour and poor function which are typically associated with poor self-discipline) and the High Function/Low Spirits group showed high Neuroticism scores (reflected in its low emotional wellbeing). The main findings from this study showed that individuals could show relatively successful patterns in one area of psychosocial wellbeing despite relatively poor functioning in other areas, and that personality plays an important role in wellbeing in old age.

The third study in this thesis included scores on Physical Fitness, Lack of Inflammation, and Lack of Morbidity to reflect the Physical Fitness domain (Chapter 5). The Physical Fitness domain also indicated a continuous pattern of wellbeing in the 2-formed groups – a high physical fitness group and a low physical fitness group. The majority of participants fell in the High Fitness group. Lack of Inflammation did not correlate with either Lack of Morbidity or Physical Fitness; however, the latter two components are likely to affect and reflect each other - individuals who are physically fit are possibly less likely to have co-morbidity, and vice-versa. This echoes results from the Cognitive Ability domain whereby functioning in one component was influenced by functioning in other components. The Low Function group had significantly higher scores on Neuroticism, a higher BMI, and a higher percentage of smokers.

In the final set of analyses (Chapter 6) I explored how individuals grouped according to all 9 components used to constitute the domains of Cognitive Ability, Psychosocial Wellbeing, and Physical Fitness. I identified 3 groups showing high or uneven patterns of wellbeing. The majority of individuals fell in the High Wellbeing group. The two other groups contained either individuals scoring relatively highly on cognitive measures but poorly on psychosocial and physical measures (the Low Bio-Psychosocial group), or individuals scoring low on cognitive measures but relatively highly on psychosocial and physical measures (the Low Cognition group); however, their scores were still lower than the average scores of the High Wellbeing group even in the measures they scored relatively highly on. The Low Bio-Psychosocial group contained a significantly higher percentage of smokers, and showed high scores on Neuroticism and low scores on Conscientiousness, whereas the Low Cognition group scored lowest average on age- 11 IQ and on the Openness trait. High childhood cognitive ability, low scores on Neuroticism, and avoiding smoking significantly differentiated the High Wellbeing group from the rest. This final study helped in developing a profile of overall wellbeing of 70- year old individuals in the LBC1936. It confirmed current ageing research (e.g., Depp & Jeste, 2009; Gerstrof et al., 2006; Ko et al., 2007; Parslow, Lewis & Nay, 2011; Smith & Baltes, 1997) that various patterns of wellbeing in old age exist, with some individuals doing well in some areas but not in others. Finally results from the final study also contributed to the existing knowledge on individual differences and cognitive and personological epidemiology (e.g. Deary, Weiss & Batty, 2010; Krueger, Caspi & Moffitt, 2000) that lifelong intelligence and personality traits are important influences of health behaviours and subsequent wellbeing, culminating in old age.

7.2 Strengths and Limitations

All participants in the study were born in the same year (1936); thus all participants had the same chronological age, which eliminated age cohort effects which could show age differences only particular to a specific group and not necessarily as a result of developmental change (e.g. Olsen, Baker, Holst & Sorensen, 2006's study on obesity trends in Denmark which were substantiated only when expressed by year of birth). Having everyone from the same cohort; however, inevitably results in losses in follow-up studies especially when participants are old.

The dataset provided me with a relatively large sample size at 1091 participants and a wide range of variables, ranging from cognitive ability scores to medical diagnoses, health, physical function, and responses to social questionnaires (Deary et al., 2007; Deary et al., in press). These were helpful in identifying differences and providing comprehensive explanations relating to specific groups of individuals. Studies with limited numbers of variables may be unable to provide comprehensive explanations of differences among groups.

All participants in the study were born in the same year. This eliminated age-cohort effects, which could show age-differences only to a specific group and not necessarily as a result of age-developmental change.

The cohort used in this study was relatively healthy. This is common when studying 70-year old individuals who volunteer for research, and who have been screened for dementia (e.g. Andrews, Clark & Luszcz, 2002; Berkman et al., 1993; Smith & Baltes, 1997). It is possible that some parts of the wellbeing continuum, or even separable groups of individuals were missed, due to the relatively high health status present in this cohort – most individuals belonged to a high wellbeing group. In fact, although I tried avoiding groups containing less than 5% of the whole sample, some groups in the study consisted of small numbers of individuals that seemed to contain distinctive qualities, such as the Low Function/High Spirits and the High Function/Low Spirits groups, setting them aside from the rest of the groups. This is sometimes an indication that the LCA analytic procedure has capitalised on chance gaps in continuous data, especially when the small groups tend to fall at the extremes of the distributions of the defining variables.

I was mostly dealing with several different continua of wellbeing (Chapters 3 and 5 illustrate this clearly), thus individuals were mostly scoring high, average or low across variables; however, 'cutting' up this continuum into groups was useful to this study to help me characterise the resulting groups, their differences, and find out key correlates of individuals ageing well.

This study was cross-sectional and so wellbeing in this cohort was only studied at one particular time-point; however, the LBC1936 is an ongoing study, with future opportunities to carry out successful ageing patterns longitudinally and follow up the current results on the stabilities of the groups.

Although a wide variety of external variables were used to describe the characteristics of the individuals comprising the groups, measures of perceptions of successful ageing were not available. How personality traits may have influenced these self-reports, and ways in which different groups might perceive success in old age and how they adjust to age-related changes, may provide important clues to scientists and health-care researchers about different types of ageing successfully.

In all studies in this thesis I winsorised extreme scores on all variables. This process enables the transformation of extreme values by limiting them to normal ranges to avoid the effect of outliers. Thus extreme values in this dataset were replaced to 3 or -3 standard deviations depending on the nature of the value. This process avoided excluding data, and simultaneously avoided spurious results from LCA due to the possible effect of outliers.

The class-solutions selected to describe the groupings of the cohort on measures of Cognitive Ability, Psychosocial Wellbeing, and Physical Fitness were ultimately based on my judgements from hierarchal analysis and from objective measures including model-fit criteria, entropy, and maximum likelihood estimation; and more subjective ones such as finding parsimony. With continuous data such as these, more groups usually indicate increasingly better fits, but this reduces parsimony. The final selection of the number of groups is ultimately subjective. Although with every selected model I justified my choices, their appropriateness is a matter of interpretation. As with other studies using LCA (e.g. Johnson et al., 2007; Nagin & Tremblay, 2004), I used the findings primarily as a means to describe the data in useful terms.

The LBC1936 is an on-going study, with future opportunities to follow up the current results on groups' stabilities and developmental patterns longitudinally.

7.3 Contributions to the Literature on Ageing

7.3.1 The domains and patterns of wellbeing in the LBC1936

As mentioned in Chapter 1, there is no clear definition of successful ageing. However, most research makes use of physical, cognitive and some form of social, psychological and emotional variables. This thesis was concerned with exploring the structure and the components of the domains of wellbeing, especially those that have a known status of changing with age, and the patterns of the domains of wellbeing. I also wanted to address some issues from previous methods' limitations.

As I noted in Chapter 1, previous attempts to group individuals did not explore how different variables may give rise (or not) to different groups. Some researchers have used only one or two aspects of wellbeing in old age (e.g. psychological wellbeing, Smith & Baltes, 1997; cognitive and physical function, Baltes & Lindenberger, 1994), whereas others who included more areas of wellbeing also included variables that are not applicable to all individuals undergoing the ageing process (e.g. Ko et al., 2007, included marriage satisfaction in their analysis). This, i.e. attempting to identify groups of individuals using an incomplete structure of wellbeing has resulted in mixed views on the definition of successful ageing, opposing perspectives on the wellbeing of individuals in old age, and consequently on the identification (if any) of patterns of wellbeing. In Chapter 1 I also highlighted the importance of applying multiple markers of wellbeing since individuals do not typically fall under one category if they are measured across a wide range of variables.

To overcome these issues I firstly included three broad domains that literature on ageing adopts – cognitive, psychosocial and emotional, and physical fitness, rather than just one or two domains. Secondly, I also applied variables that either have been shown to change with age or are applicable to all ageing individuals, such as variables relating to quality of life and emotional wellbeing. Thirdly, I included both objective-based measures to represent cognitive and physical fitness and self-report measures to represent psychosocial and emotional wellbeing to include a wide range of markers of wellbeing and find if, and how, these contributed to different patterns of wellbeing. Finally, I studied the domains of wellbeing individually and together. This helped in finding out which domains gave rise to patterns and which did not. There is more detail on these variables in Chapter 2.

My thesis showed that components in cognitive and physical domains are correlated thus poor functioning in one was related to poor functioning in others, but this was not the case in the psychosocial domains. Secondly, and in a related vein, results demonstrated that wellbeing in old age generally reflects a dimensional pattern of high-, average- and low- scoring individuals across cognitive, psychosocial and physical domains of function, with evidence of the presence of groups with uneven profiles in some, but not all, of the domains. These findings supported two main bodies of research.

As I noted in Chapter 1, literature commonly depicts the linear and process approaches as incompatible; however, my results showed that both approaches might apply. In the cognitive (Chapter 3) and physical domains (Chapter 5), the linear approach seemed more fitting (groups of individuals either scored highly or poorly consistently on all variables). However, when including components of psychosocial wellbeing (Chapters 4 and 6), the process approach was applicable; that is, some groups of individuals showed inconsistent patterns by scoring relatively highly on some, but not all, of the components being studied. Given the results from the Cognitive (Chapter 3) and Physical (Chapter 5) domains, and the established correlations between these two domains in the literature (Anstey & Smith, 1999; Anstey et al., 2001; Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994) and between the components (except for Inflammation) of these domains (shown in Chapter 6) in this thesis, it seemed that function on components of these two domains in old age was either good or poor. However, results also demonstrated that when components of psychosocial and emotional wellbeing were included in the analysis there is evidence of the presence of groups. This is possibly because psychosocial and emotional wellbeing reflect the individual’s own adjustment to physical, cognitive and other changes that have been taking place that are possibly not within the individual’s control. Thus, psychosocial and emotional components showed if, and how, individuals were dealing with poor function in some components. For example, the Low Function/High Spirits group in Chapter 4 was a clear example of a group of individuals who despite their poor physical function still maintained relatively high emotional wellbeing. This group seemed to accept its limitations, and used other skills to compensate for any losses experienced.

Previous literature has not shown how individuals with poor function in some domains may use psychosocial and emotional skills, but because in my thesis I adopted a multivariate approach, I was able to explore cognitive, physical, psychosocial, and emotional patterns together, and find out if there are people who adopt uneven patterns of wellbeing to adjust to their own needs.

7.3.2 Correlates of wellbeing in the LBC1936

Studies in this thesis allowed exploration of external variables distinguishing amongst the resulting groups to help develop their profiles. Results from Chapter 6 demonstrated three key correlates of overall wellbeing in old age: lifelong intelligence, personality traits, and health behaviour.

In this thesis higher age-11 IQ was associated with better wellbeing at age 70 (age- 11 IQ significantly distinguished amongst the groups in all 4 studies; the strongest effect sizes were found in Chapters 3 and 6 in which Cognitive Ability was a core measure in grouping individuals). This finding supported previous results (Batty, Deary & Gottfredson, 2007; Deary, 2008; Deary, 2010; Johnson, Corley, Starr & Deary, 2011) on the effects age- 11 IQ seems to have on wellbeing in old age. The high childhood IQ-better health association may be explained in terms of the system-integrity hypothesis, whereby intelligence-health associations reflect overall better physiological integrity (Deary, 2008; Deary, Weiss & Batty, 2010; Whalley & Deary, 2001). Cognitive ability may also have pervasive characteristics that carry on throughout the lifespan because it is associated with individual differences in health awareness and consequent behaviours

- individuals with higher cognitive ability are better equipped to manage their health (Deary, 2005, 2008).

Similarly to childhood cognitive ability, personality is also associated with individual differences and health behaviours (Deary, Weiss & Batty, 2010). In this thesis, personality traits, especially scores on the Neuroticism trait consistently distinguished amongst the groups – individuals with low scores on this trait had accompanying good wellbeing (Chapters 3 -6), indicating that low scores on this trait are important for successful wellbeing in old age. Individuals in high wellbeing groups in all empirical studies (Chapters 3 – 6) also possessed other personality traits that seem important for psychological wellbeing in old age, namely high scores on traits of Extraversion, Conscientiousness, Agreeableness, and Openness. A likely explanation behind these associations is that health behaviours are typically reflected in one's personality; for example high Neuroticism, low Conscientiousness and low Agreeableness are related to health-harming behaviours, such as smoking (Terracciano & Costa, 2004), whilst high scores on Conscientiousness are related to health-promoting behaviours, such as exercising (Bogg & Roberts, 2004). These patterns were in fact illustrated in this thesis- groups with high scores on the Neuroticism trait and low scores on the Conscientiousness trait were associated with unhealthy behaviour, mainly smoking and low physical function and physical fitness, had more co-morbidity and were taking more medications (Chapters 4 and 6). Like cognitive ability, individuals with the 'right' personality traits seemed to be able to manage their health better.

This thesis also demonstrated the importance of health behaviour in later life, especially that of avoiding smoking. Throughout the thesis there were a significantly lower percentage of smokers in the high wellbeing groups (Chapters 4 -6). This association can be explained through intelligence and personality differences as illustrated above. Individuals with higher cognitive ability and lower scores on Neuroticism avoided (or quit) smoking – this associative pattern was illustrated in the High Wellbeing group. These results supported previous research in depicting the typical smoker's profile - high Neuroticism, low Conscientiousness, and lower cognitive ability (Ball et al., 1997; Conway et al., 2003; Deary et al., 2003; Kornor & Nordvik, 2007; Kubicka, et al., 2001; Taylor et al., 2003; Roberts et al., 2007; Richards et al., 2003; Terracciano & Costa, 2004; Vollrath & Torgersen, 2002; Whalley et al., 2005). These cross-model associations with smoking are probably a reflection of a lack of cognitive and personality skills to deal with stress. Individuals with higher cognitive ability and with higher scores on Conscientiousness and lower scores on the Neuroticism trait may be more aware of the health risks involved and may be more disciplined in avoiding health-harming behaviours.

This thesis has supported current literature that intelligence and personality traits are associated with health behaviour, health and general wellbeing in old age. Given the wide variation of cognitive ability, even in childhood, and of various personality traits, makes the possibility of the whole population ageing well a challenge. Finding out the causes underlying associations between cognitive ability, personality and health may help in advancing this field and possibly understanding better how to address health inequality issues amongst individuals most at risk. Furthermore, awareness of these individual differences amongst health-care professionals may also contribute in applying tailored treatment, better patient-practitioner relations, and improved compliance. Policy-makers also need to take these differences and inequalities into consideration when developing policies and prevention programs; personalised healthcare programs and services may help in targeting these issues directly.

7.4 Recommendations for future research

This thesis investigated the structure of the domains of wellbeing in old age and the way individuals grouped together on these domains using a cross-sectional design, thus it was not possible to interpret direction of effects amongst correlations. Along the lines of the common-cause hypothesis (Baltes & Lindenberger, 1994) future work needs to investigate further the correlations and underlying causes of cognitive-physical associations. This study also explored correlates of patterns of wellbeing. However, the mechanisms underlying associations among intelligence, personality and health behaviours still need to be explored and understood. Identifying casual factors will help in understanding better the relations among these lifelong traits and health behaviour and wellbeing. This will also contribute to develop further understanding to the much-mentioned theoretical concepts of the ‘common-cause hypothesis’, the ‘cognitive and brain reserve’ and the ‘system-integrity hypothesis’. It will also help in dealing better with existing health inequalities arising from these traits.

Furthermore, since there was evidence for uneven profiles when psychosocial and emotional components were included, future work should also include measures of perceptions of successful ageing, and attitudes to ageing questionnaires from the participants themselves, the latter of which has now been collected for Wave 2 of this cohort. Given that many older people still rate themselves as ageing successfully even if they do not meet objective criteria in areas such as physical fitness (Depp et al., 2010), a subjective approach included with other more objective domains may give a different perspective on how individuals may group on wellbeing in old age. This may provide important clues on how different groups may perceive success and wellbeing in old age and how they adjust to age-related decline. It is suggested that future research would adopt a more all-inclusive approach to studying patterns of wellbeing in old age.

Similar studies to this in other cohorts will be useful to find out the extent of the possible revalidation of these results. It would also be informative to find out how patterns of wellbeing may emerge and differ in unhealthy cohorts.

The longitudinal design of this cohort study will be useful to follow up on developmental patterns that define successful cognitive, psychosocial, and physical ageing. Studies from this cohort over time may reveal how groups may change longitudinally and if participants move between groups. This will also test the robustness of the groups found in this cohort. A longitudinal design will also help in finding out which groups occur at different ages, thus help in finding out how patterns of wellbeing manifest themselves in different age-groups. Studies from other cohorts may also be useful as comparisons to find out how the results may vary amongst different samples.

Lastly, it would be useful and beneficial to translate the findings from this thesis into practical use. There is increasing interest into the processes of successful ageing. Educating the public, and working closely with health-care practitioners and policy-makers may contribute to balancing health inequalities. There are already emerging fields of cognitive and personological epidemiology that aim to diminish health and wellbeing inequalities by providing care and support as needed (Deary, Weiss & Batty, 2010). Awareness of individual differences relating to these traits and their behavioural influences among policy-makers and health-care professionals may address clinical issues on risk prevention, improved compliance and better patient-practitioner relationships. We already know what contributes to high wellbeing in old age; the next step is making this information useful to individuals with a poorer outlook.

7.5 Final comments

7.5.1 What is successful ageing?

Results from this thesis showed that a number of individuals consistently scored relatively highly on all domains of cognitive and physical function, and psychosocial and emotional wellbeing. Results also showed that some individuals who did not have high scores on physical and cognitive function seemed to be able to compensate with psychosocial and emotional skills. This suggested that adjusting well to changes and situations that cannot be changed is possibly part of successful ageing, as the patterns from the psychosocial domain/components showed. Finally, results also suggested that intelligence and personality traits, and health behaviours are associated with high wellbeing.

Thus, as suggested by my results and my interpretation of these, successful ageing seems to firstly be constituted of good enough physical and cognitive function to maintain independence by having the necessary capacities to manage daily activities, such as cooking and bathing, and to engage in something that gives the individual joy, such as painting or gardening; and secondly, to possess a good set of psychological, emotional and social skills to make necessary compensations where possible, to adapt to changes that are irrevocable, and to be aware of these differences and ultimately be wise enough to accept them in life outcomes.

Maintaining these functions and skills is a lifelong process, the outcome of which culminates in old age. Thus, successful ageing is not just about old age per se, but about a continuous interplay of lifelong traits, behaviours and experiences. This thesis in fact also demonstrated that ageing is an individual differences process associated with intelligence and personality traits, and health behaviours. Because of the wide variation in these traits amongst the whole population, a level grounding does not seem conceivable - not everyone will engage in a healthy lifestyle and not everyone will age well. However, with increased awareness on individual differences and health inequalities in the population and with help from policy-makers and health-care professionals to develop and apply tailored and personalised care, individuals who are at risk may have a better opportunity to age better and healthier.

7.5.2 In how many ways can one age successfully?

This thesis showed that although cognitive and physical functions are necessary to maintain wellbeing into old age, it also demonstrated that the use of psychosocial and emotional skills help in adjusting to irrevocable declines. However, to what extent did compensation in one domain ‘make up’ for the decline in another to help in still achieving successful ageing? A physically and cognitively healthy individual may be emotionally fraught and feeling socially isolated. Another may have a terminal illness or a physically limiting and disabling condition, but he might still have his cognitive capacities, has accepted his situation and feels content because he still enjoys writing and is surrounded by family and friends. Lastly, an individual may still be physically healthy, is emotionally adjusted, and has social support; however she has dementia, which has left her unaware of her surroundings and unable to live independently. These examples highlight the importance of the good function of all three domains of wellbeing; however, they are also aimed to represent segments of the population who are not ageing optimally in all three domains (results in this thesis have also illustrated this). The question is, are all these individuals ageing successfully in different ways or have they missed their chance because of poor patterns in one or some domains? In my views, based on the results from this thesis, each person has to find his own way to age successfully. Ideally, optimal performance across all domains of wellbeing would be achieved by all; however, realistically it seems that each person has to make the best of what he has. Growing old is part of a life narrative, which may involve a sense of life's personal meaning, accepting constraints, failures and limitations, and embracing losses and gains, decline and growth, and achieving a feeling of fulfilment. Individuals who continuously modify their goals according to their changing personal circumstances are more likely to adjust. Psychosocial and emotional abilities are a set of skills that can be adopted even by individuals who are not highly cognitively and physically fit; and although my results showed that successful ageing possibly requires high function in all domains of wellbeing, there are more ways to adjust to the ageing process in a way that is psychologically fulfilling; in a way it goes along the lines of the serenity prayer:

> God grant me the serenity to accept the things I cannot change,
> the courage to change the things I can, and the wisdom to know
> the difference.

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